

JSC/EC5 U.S. Spacesuit Knowledge Capture (KC) Series Synopsis

All KC events will be approved for public using NASA Form 1676.

This synopsis provides information about the Knowledge Capture event below.

Topic: Near-Earth Asteroids: Threats and Opportunities

Date: July 31, 2013 **Time:** 11:30-1:00 pm **Location:** JSC/B5S/R3102

DAA 1676 Form #: 30750

A PDF of the presentation is also attached to the DAA 1676 and this is a link to all lecture material and video: <\\js-ea-fs-01\pd01\EC\Knowledge-Capture\FY13 Knowledge Capture\20130731 Love Near-Earth Asteroids\For 1676 Review and Public Release>.

*A copy of the video will be provided to NASA Center for AeroSpace Information (CASI) via the Agency's Large File Transfer (LFT), or by DVD using the USPS when the DAA 1676 review is complete.

Assessment of Export Control Applicability:

This Knowledge Capture event has been reviewed by the EC5 Spacesuit Knowledge Capture Manager in collaboration with the author and is assessed to not contain any technical content that is export controlled. It is requested to be publicly released to the JSC Engineering Academy, as well as to CASI for distribution through NTRS or NA&SD (public or non-public) and with video through DVD request or YouTube viewing with download of any presentation material.

Presenter: Dr. Stan Love

Synopsis: Dr. Stan Love's presentation reviewed the basics of NEAs: how many there are, how likely they are to hit the Earth, ways to prevent a threatening asteroid from hitting us, and some thoughts on human exploration of these interesting objects.

Biography: Dr. Stan Love is a NASA astronaut at the Johnson Space Center. He served as a crew member and spacewalker on space shuttle flight STS-122 in 2008 and worked as a Capcom for many shuttle and International Space Station missions. He has participated in numerous terrestrial spaceflight analog expeditions, including two Antarctic field seasons with ANSMET. He previously worked as a spacecraft engineer at Jet Propulsion Laboratory and as a postdoctoral researcher in planetary science at Caltech and at the University of Hawaii. He holds a bachelor's degree in physics from Harvey Mudd College, and a master's and doctorate in astronomy from the University of Washington.

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Near-Earth Asteroids: Threats and Opportunities

**EVA Knowledge Capture
2013 July 31**

Stan Love, CB and YA

Outline

1. What's Out There?
2. Mitigating Asteroid Hazards
3. Human Missions to Asteroids
4. Conclusion

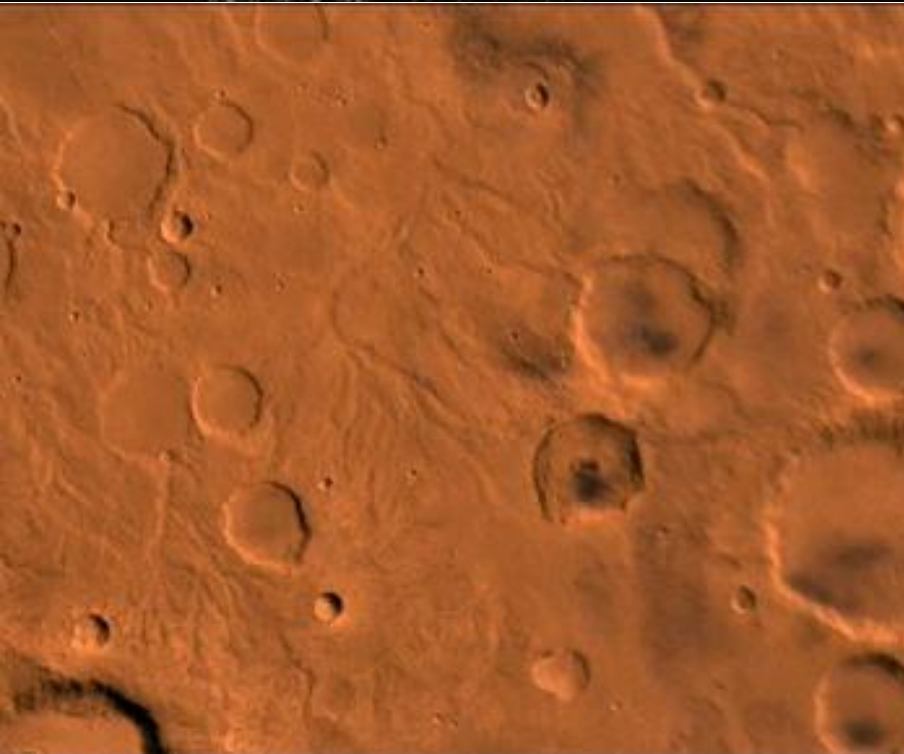
1. What's Out There?



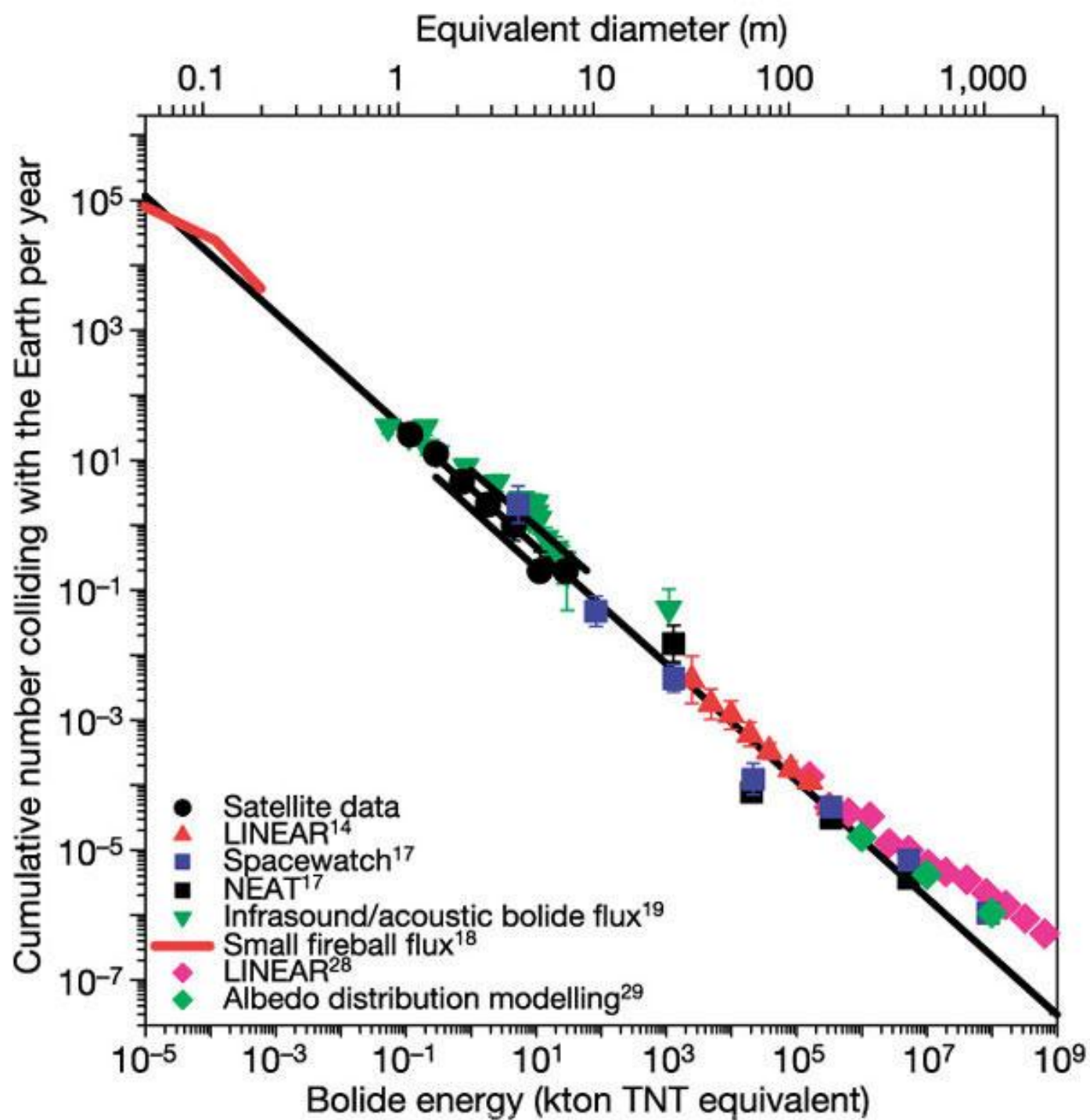












Impactor Sizes and Frequencies

<u>Description</u>	<u>Size</u>	<u>Energy</u>	<u>Average Interval</u>
meteorite	10 cm	low	~1 min
Chelyabinsk	18 m	440 kT	~100 y
Tunguska	50 m	10 MT	~3,000 y
civilization ender	1.5 km	10^6 MT	~1,000,000 y
dinosaur killer	10 km	10^8 MT	~100,000,000 y

"Average" deaths per year from asteroids:

"Average" deaths per year from asteroids:

about 100

"Average" deaths per year from asteroids:

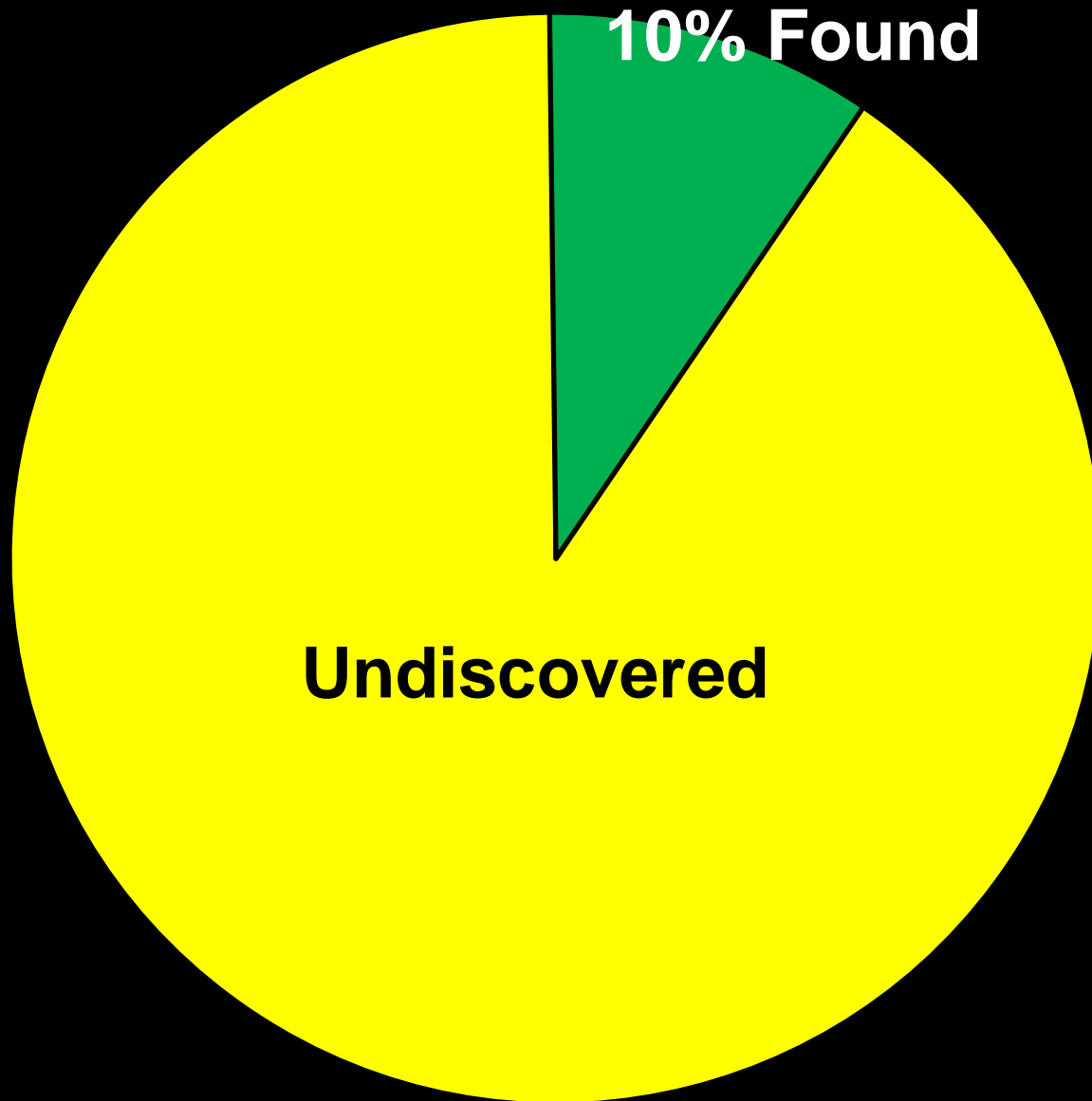
about 100

(Sharks: 5. Lightning: 24,000.)

Largest Near Earth Asteroid: 433 Eros



30 km



~100,000 Near Earth Asteroids
>140 m



~20,000 Potentially
Hazardous Asteroids
>140 m, <0.05 AU

By 2020?



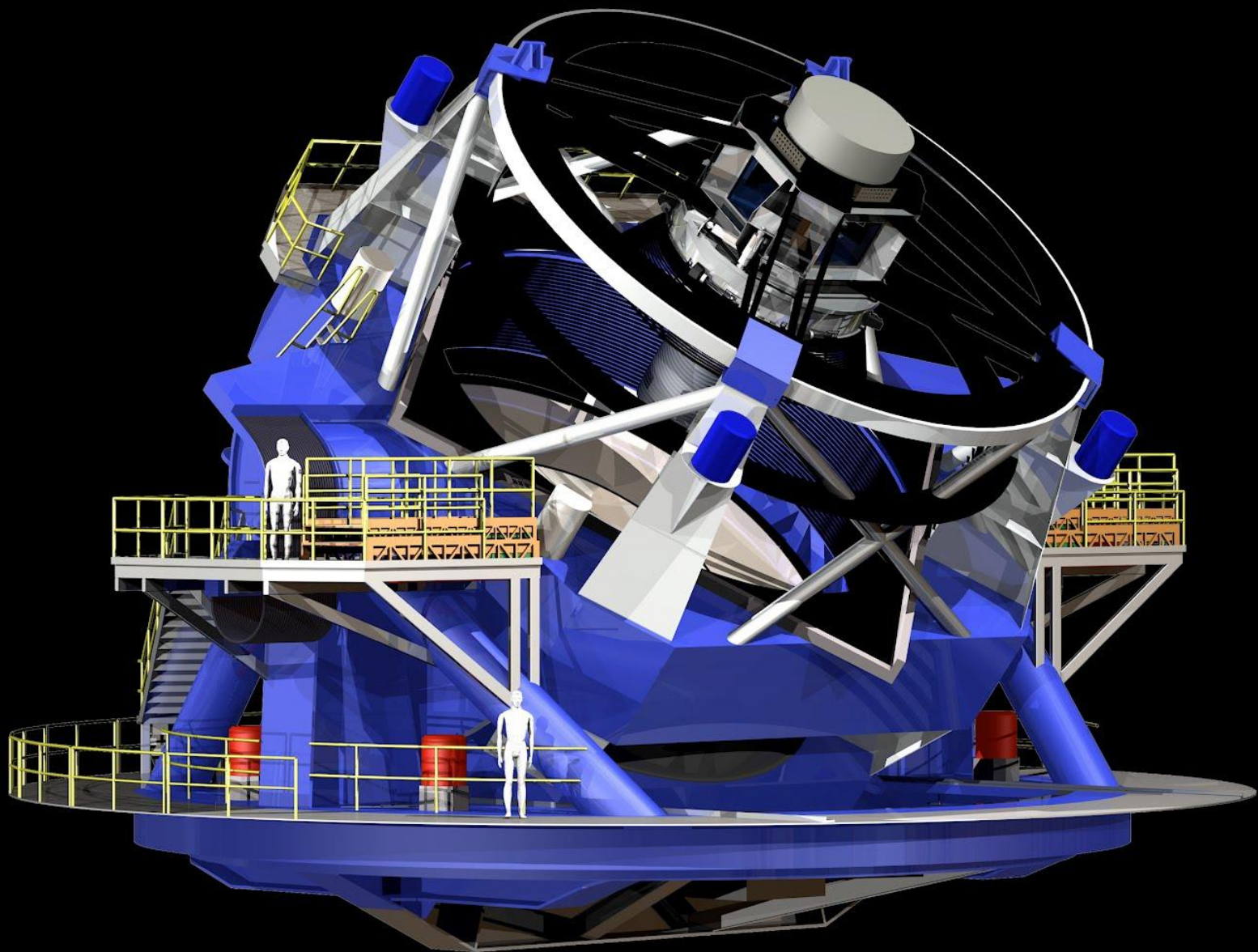
~20,000 Potentially
Hazardous Asteroids
>140 m, <0.05 AU



21/12/2031 06:58







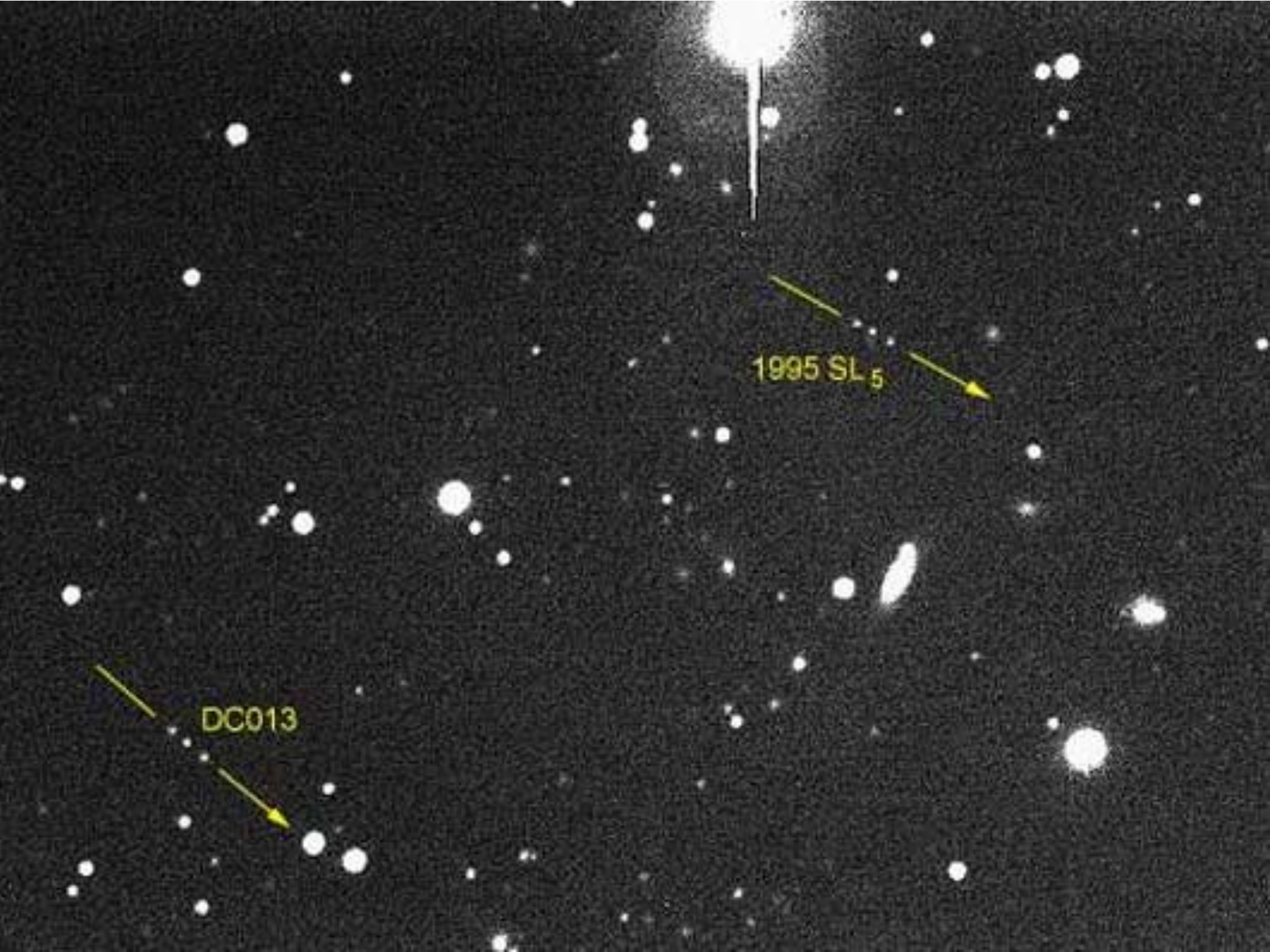
2. Mitigating Asteroid Hazards





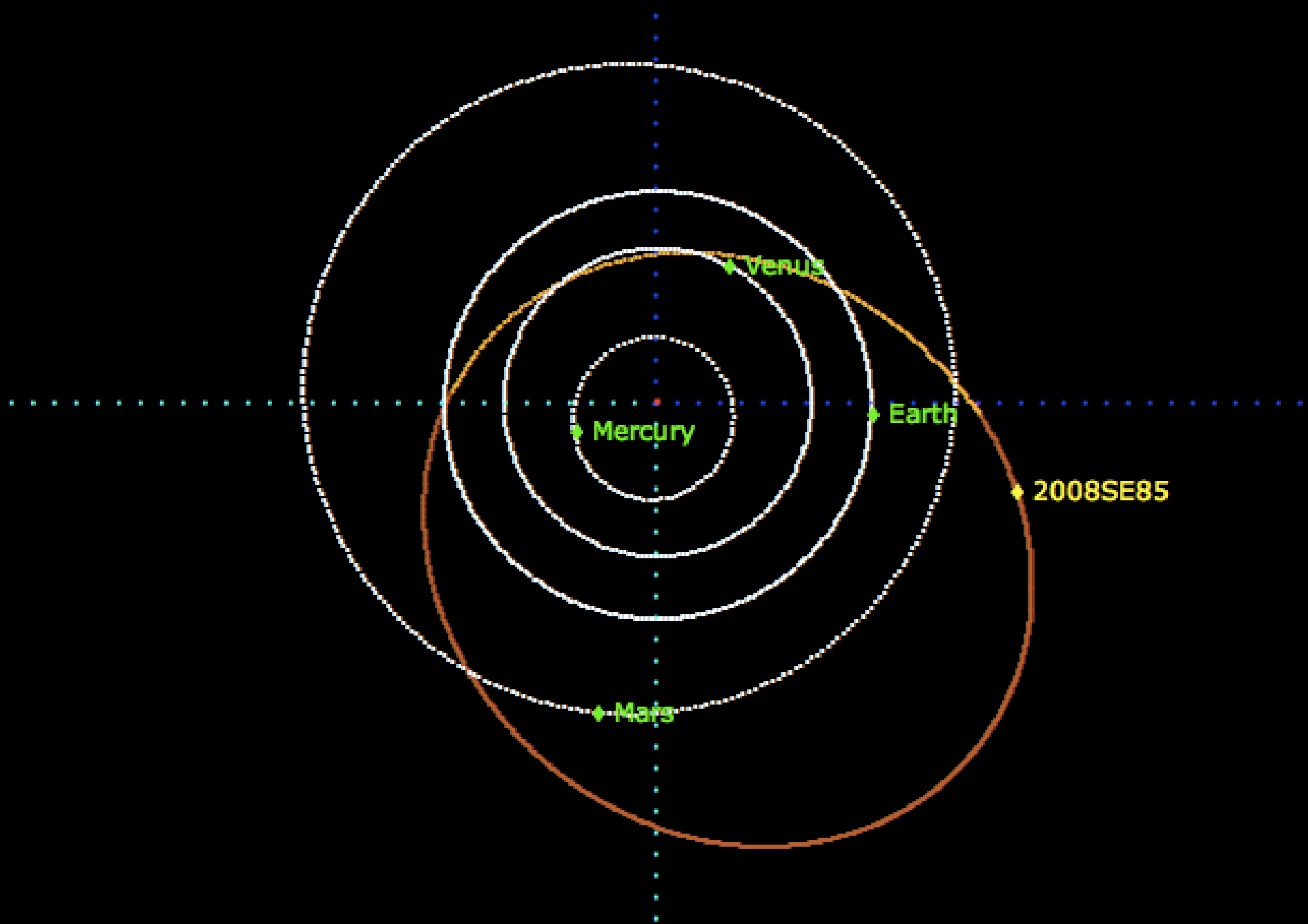
Warning time

Zero to a few hours



1995 SL₅

DC013



Decades

B R U C E W I L L I S



A JERRY BRUCKHEIMER PRODUCTION

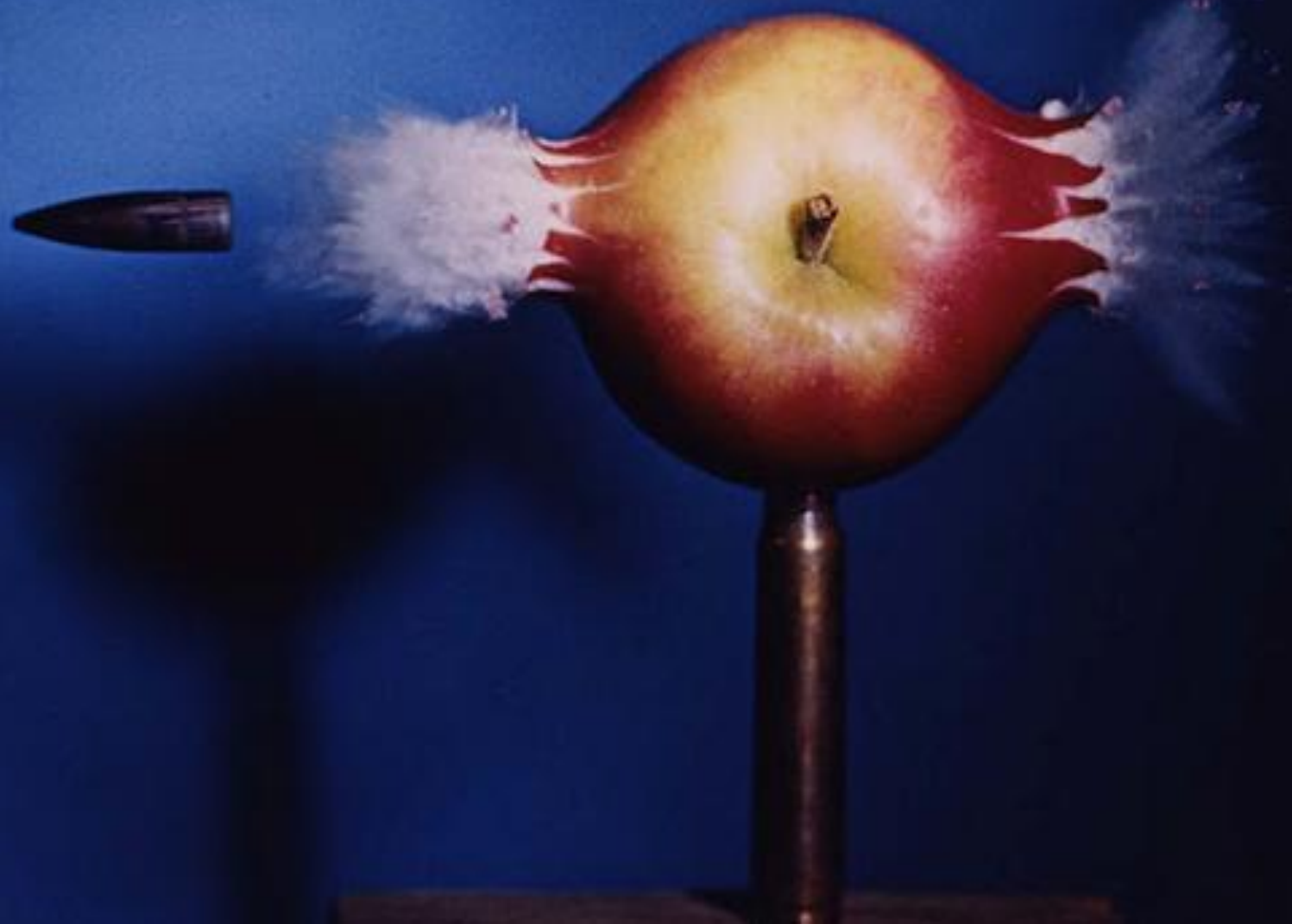


ARMAGEDDON

A MICHAEL BAY FILM

ONE PICTURES A JERRY BRUCKHEIMER PRODUCTION PRESENTS A MICHAEL BAY FILM "ARMAGEDDON" BRUCE WILLIS "ARMAGEDDON" BILLY BOB THORNTON LIV ULLER BEN AFFLECK WILL PATTON
PETER STAMMARO KEITH DAVID STEVE BUSCEMI TREVOR RABIN MICHAEL KAPLAN MARK GOLDBLATT CHRIS LEBENDON GLEN SCANTLEBURY MICHAEL WHITE
JAMON SCHWARTZMAN JONATHAN HENSLEIGH JIM VAN WYCK CHAD ORAN ROBERT ROY POOL JONATHAN HENSLEIGH TONY GILROY SHANE SALERNO
JONATHAN HENSLEIGH J.E. ABRAMS JERRY BRUCKHEIMER GAIL ANNE HURD MICHAEL BAY MICHAEL BAY





There must be no big pieces.



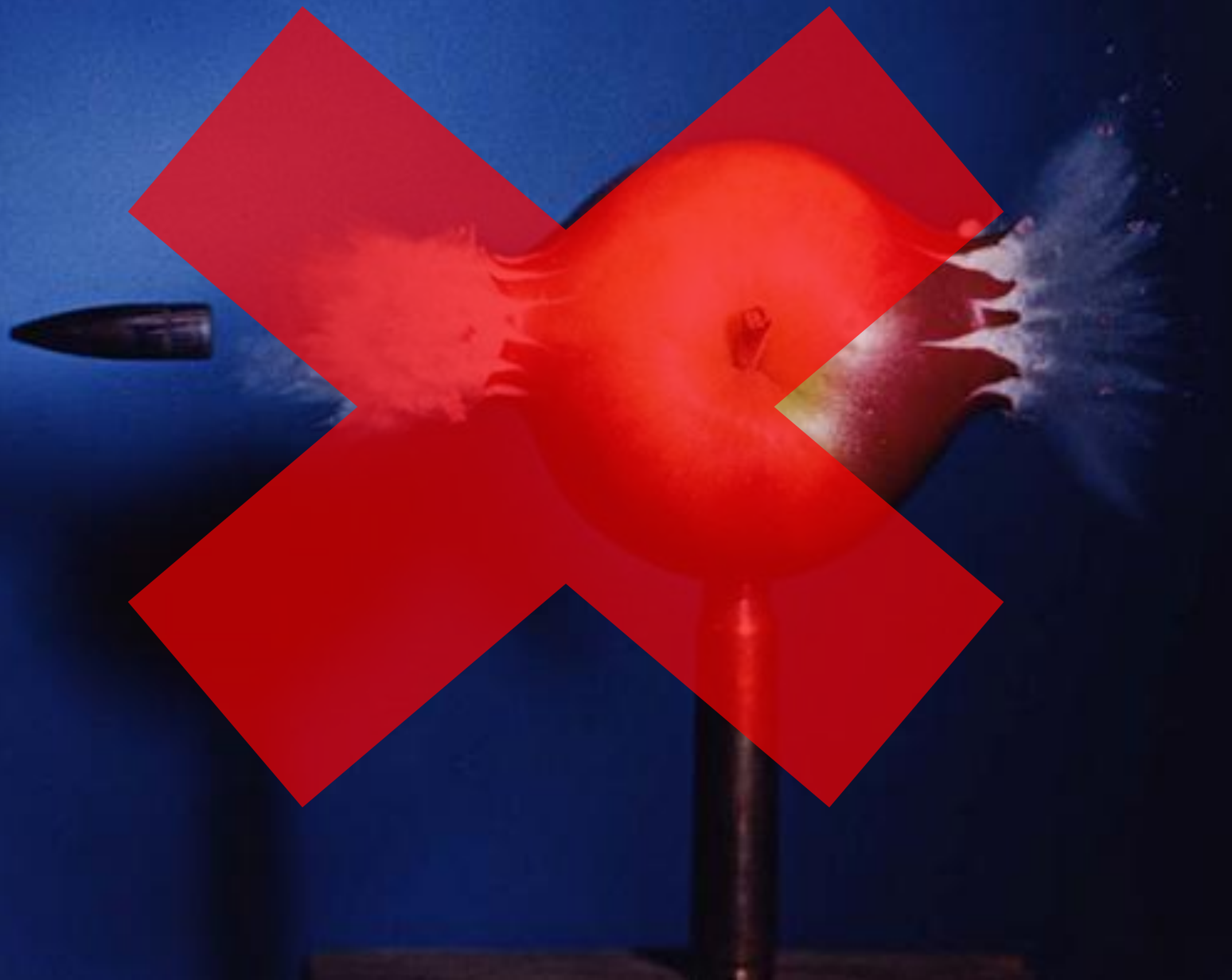
There must be no big pieces.

Rubble absorbs impulses.

There must be no big pieces.

Rubble absorbs impulses.

Must use 3x more energy.



A photograph of three martial artists in white uniforms performing a synchronized jump or kick in a dark setting. The central figure is a man with a black belt, looking upwards with his arms raised. Two other figures are in mid-air, performing a high kick or jump. The background is dark with some horizontal lines visible. The text '~1 cm/s' is overlaid in the center.

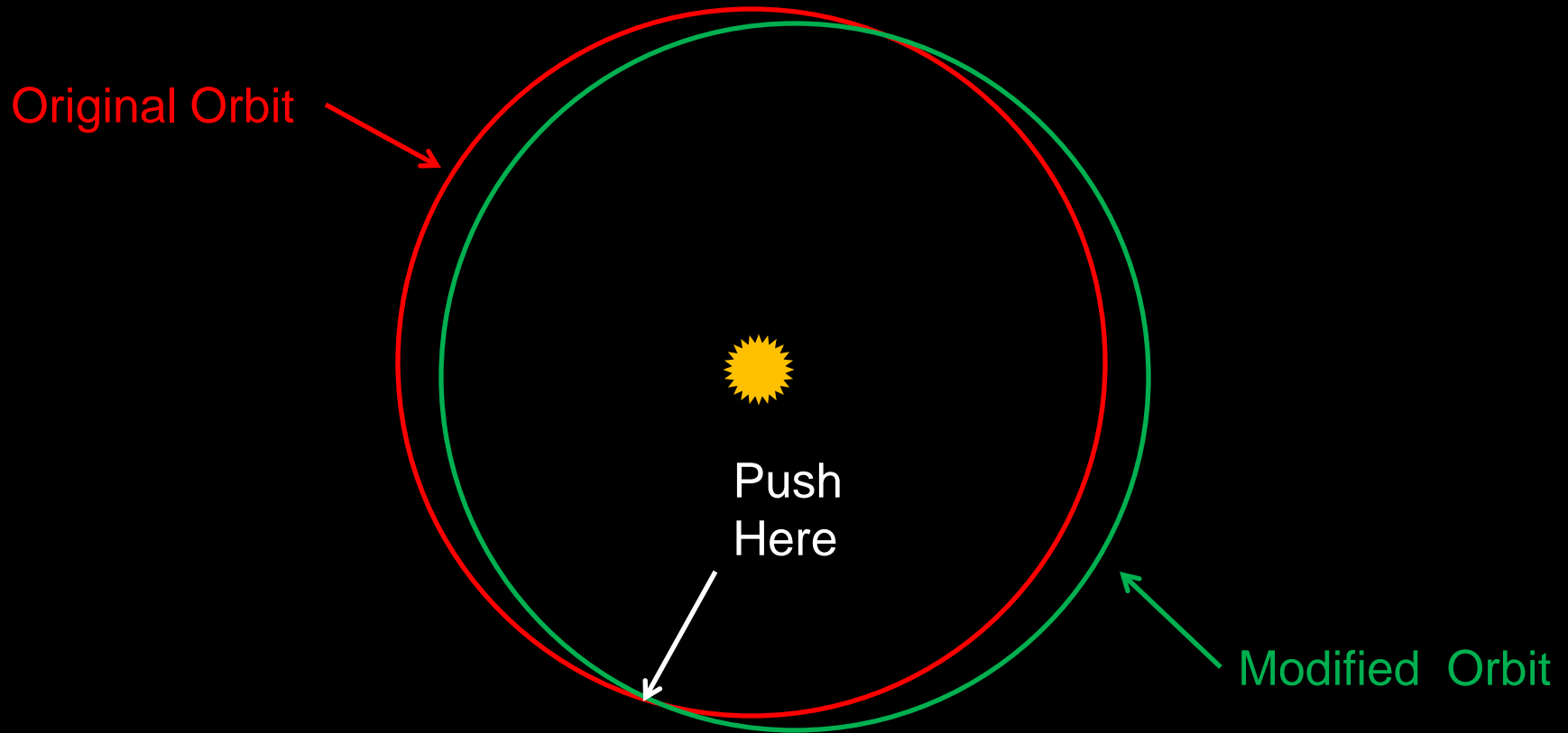
$\sim 1 \text{ cm/s}$



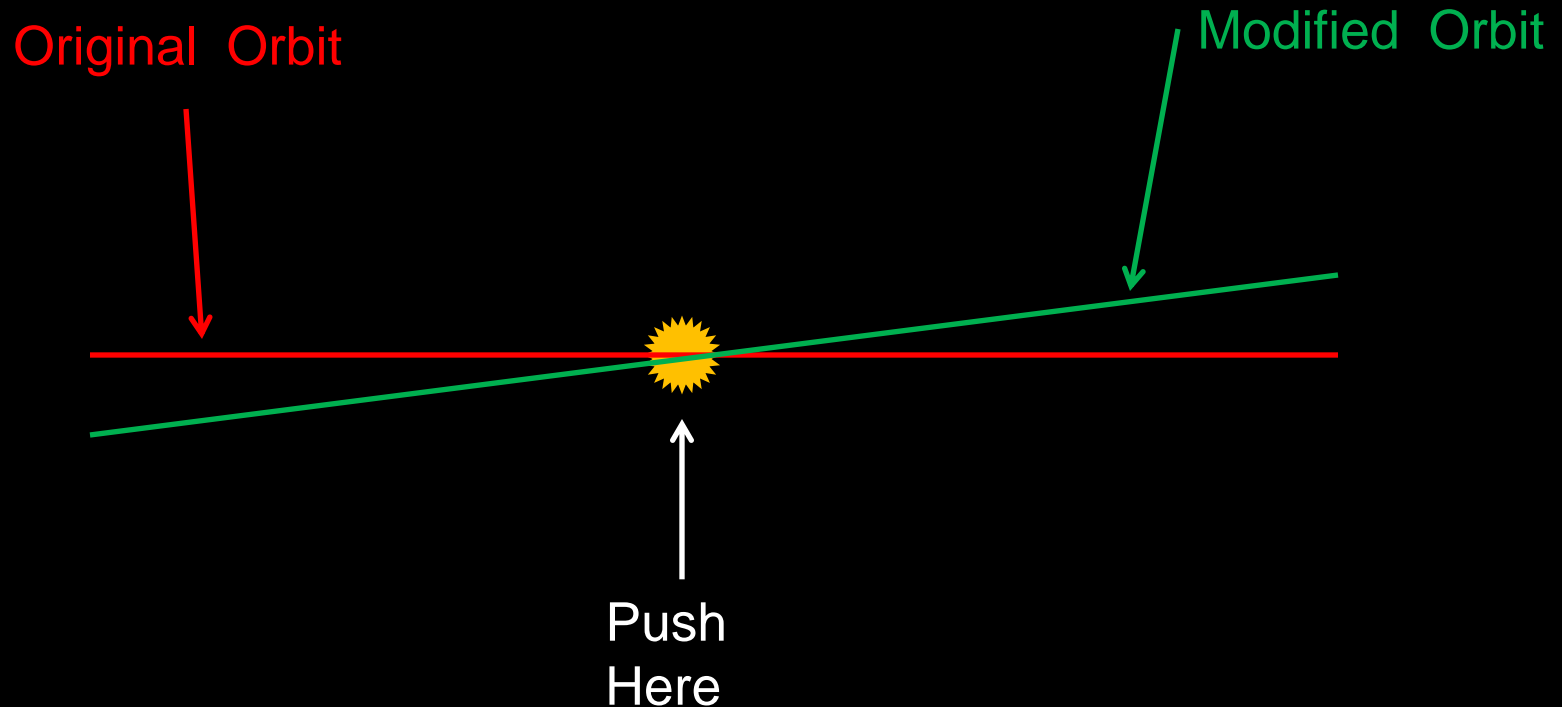
PULL

MIDVALE
SCHOOL FOR
THE GIFTED

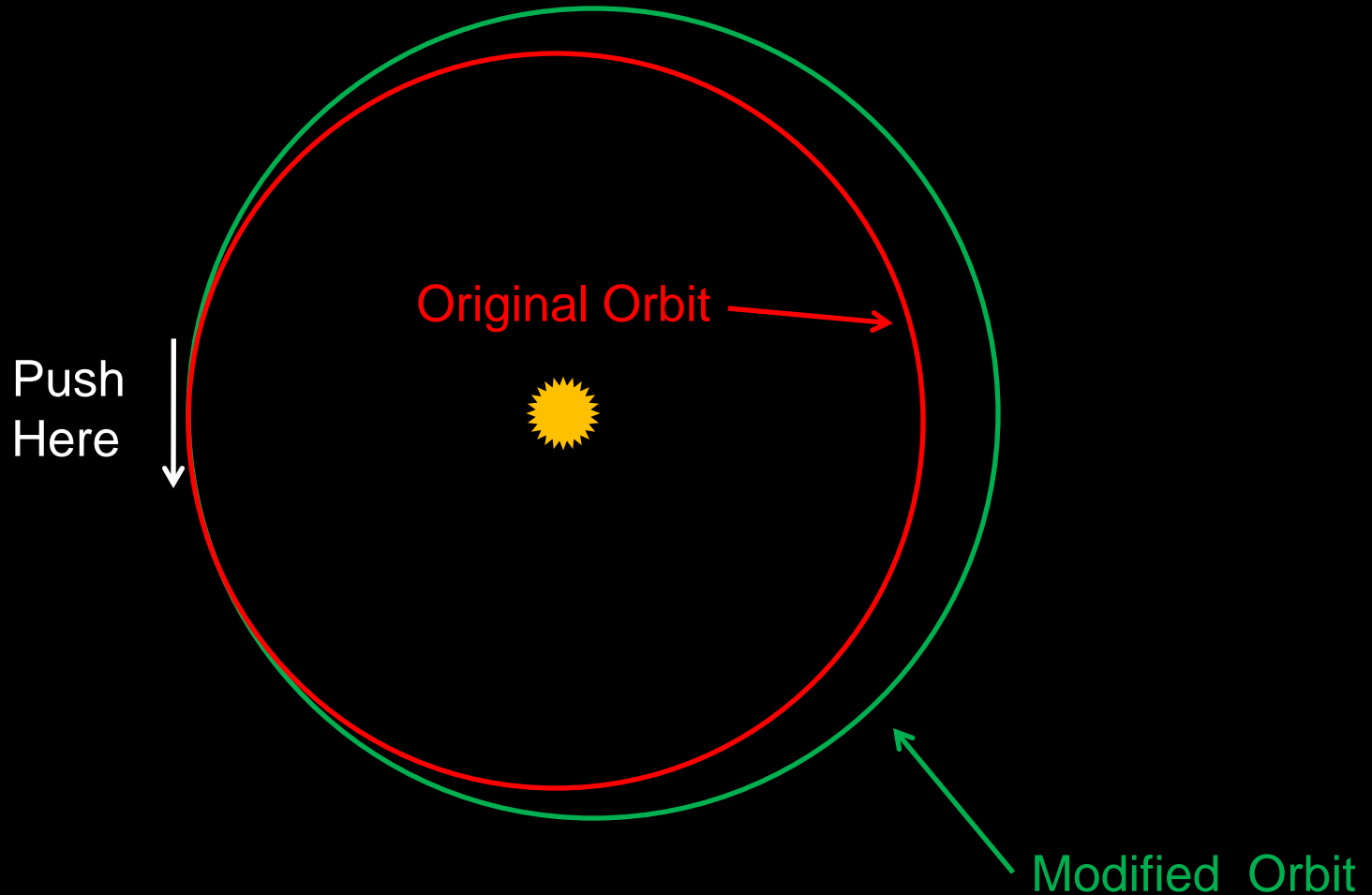
Radial: $d_{\max} \approx 2\Delta v P/\pi$



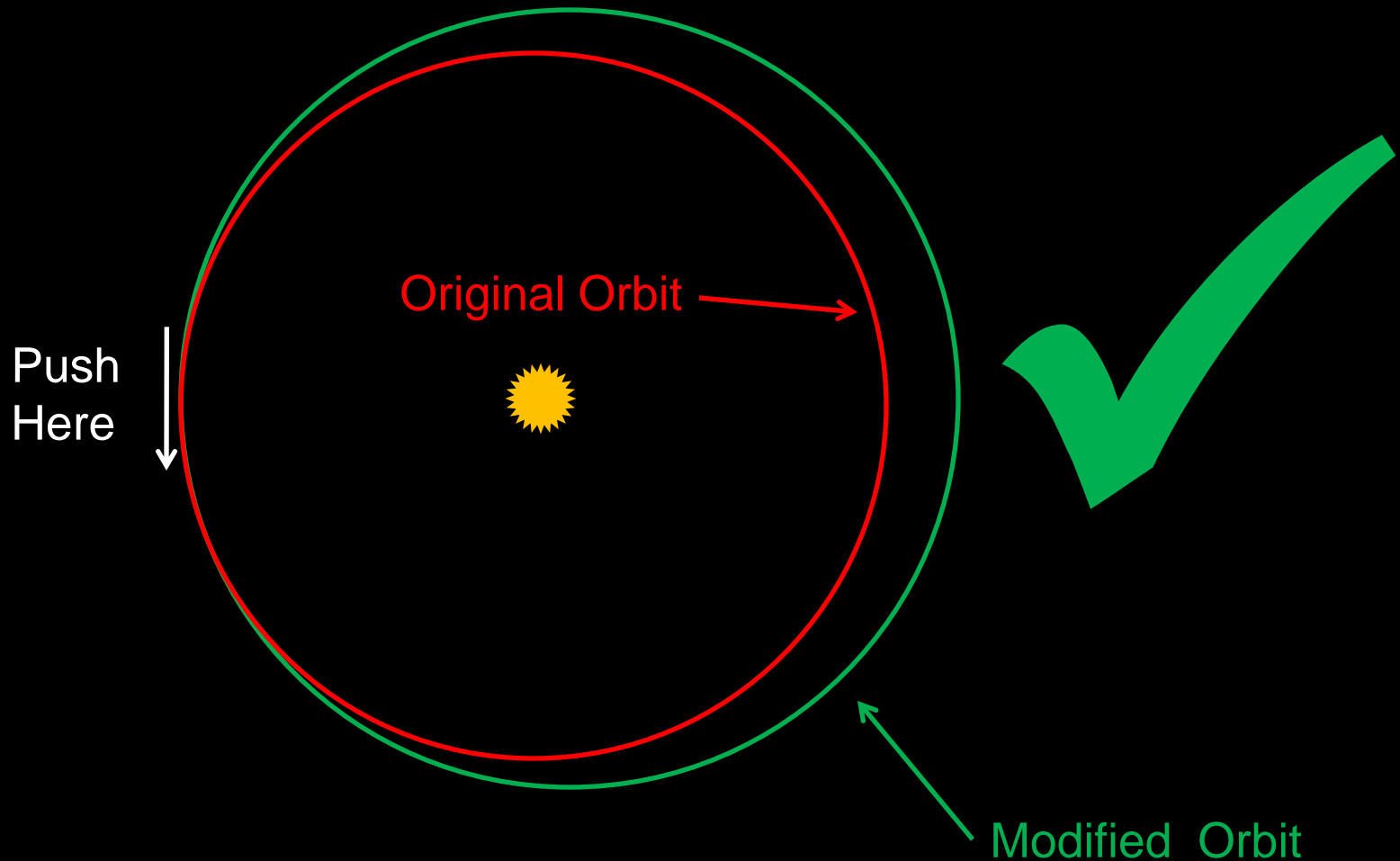
Out-of-plane: $d_{\max} \approx \Delta v P / 2\pi$

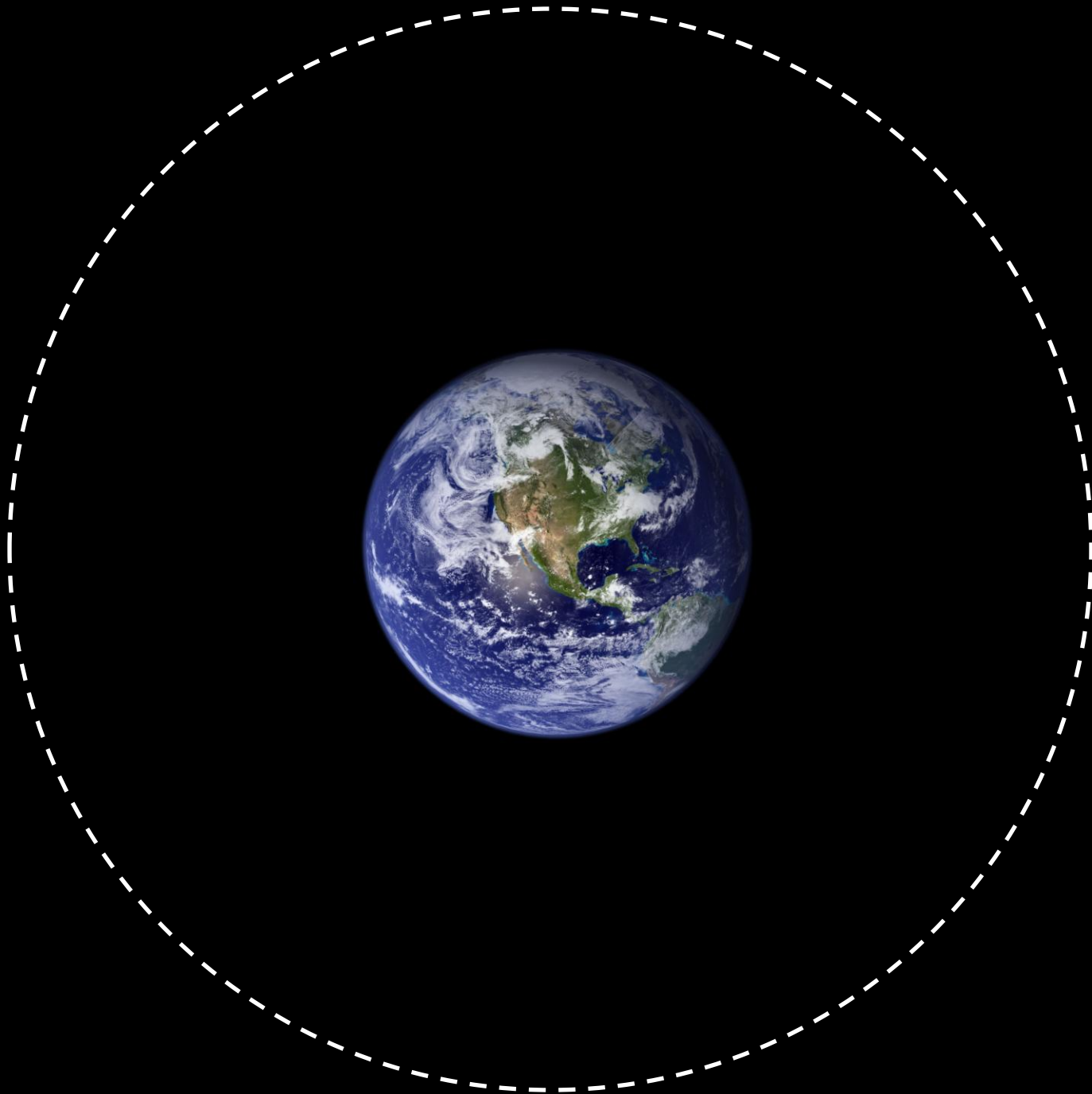


Tangential: $d \approx 3\Delta vt$



Tangential: $d \approx 3\Delta vt$







A string of colorful, numbered beads is visible in the upper left portion of the image. The beads are in various colors including red, white, yellow, and green, and some have numbers like '8' and '9' on them. The background is dark and out of focus, with a large, bright, circular light source visible in the lower right corner.

Miss distance ~100x greater.



Miss distance ~100x greater.

Must avoid "keyholes."

Rendezvous:



Hard, but we've done it.

Landing:

Hard, but we've done it.



High speed targeting:

Hard, but we've done it.

Anchoring:

Very hard, no good solution.





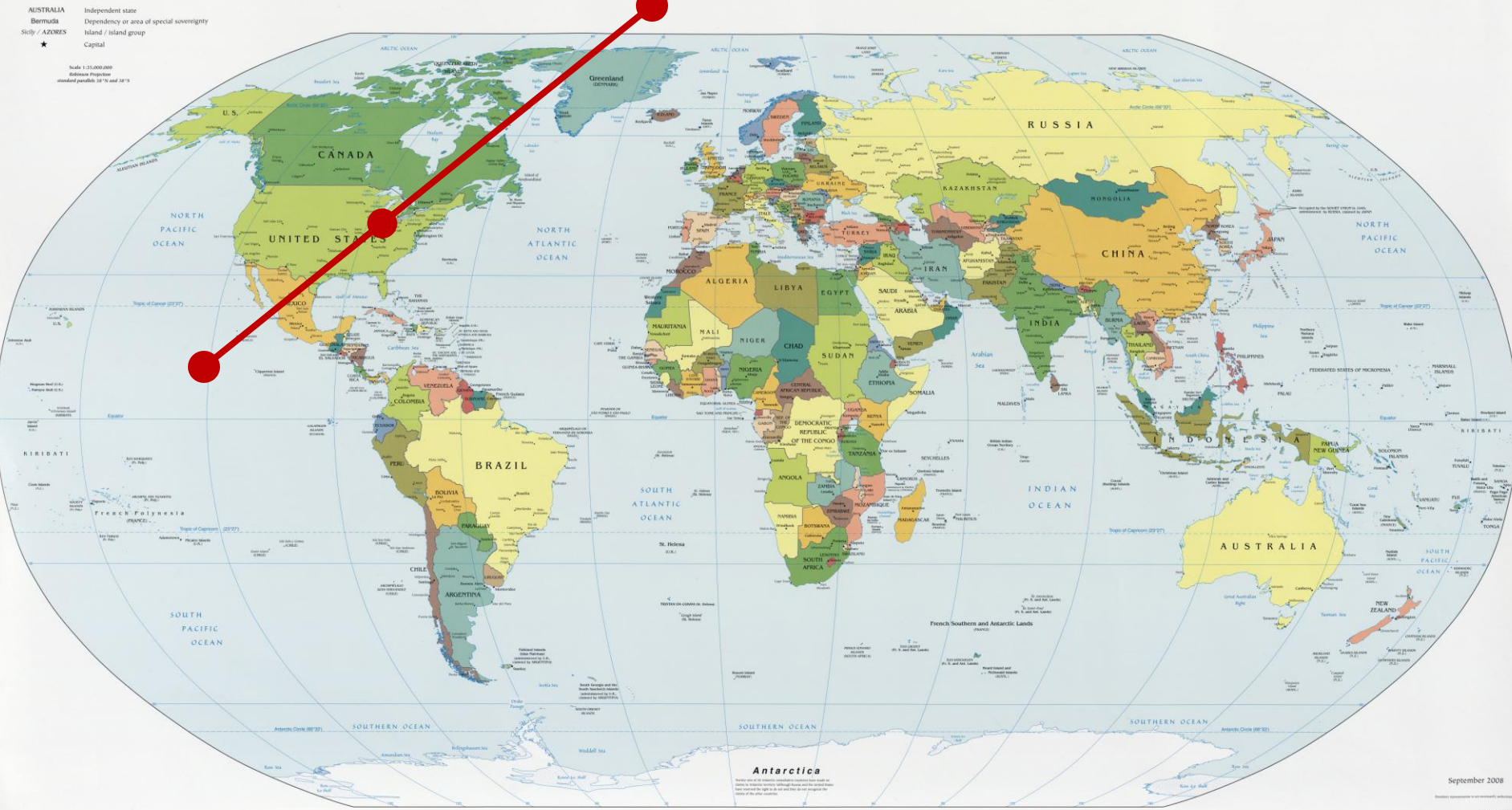
Drilling and Excavating:

Extremely hard, no solution.

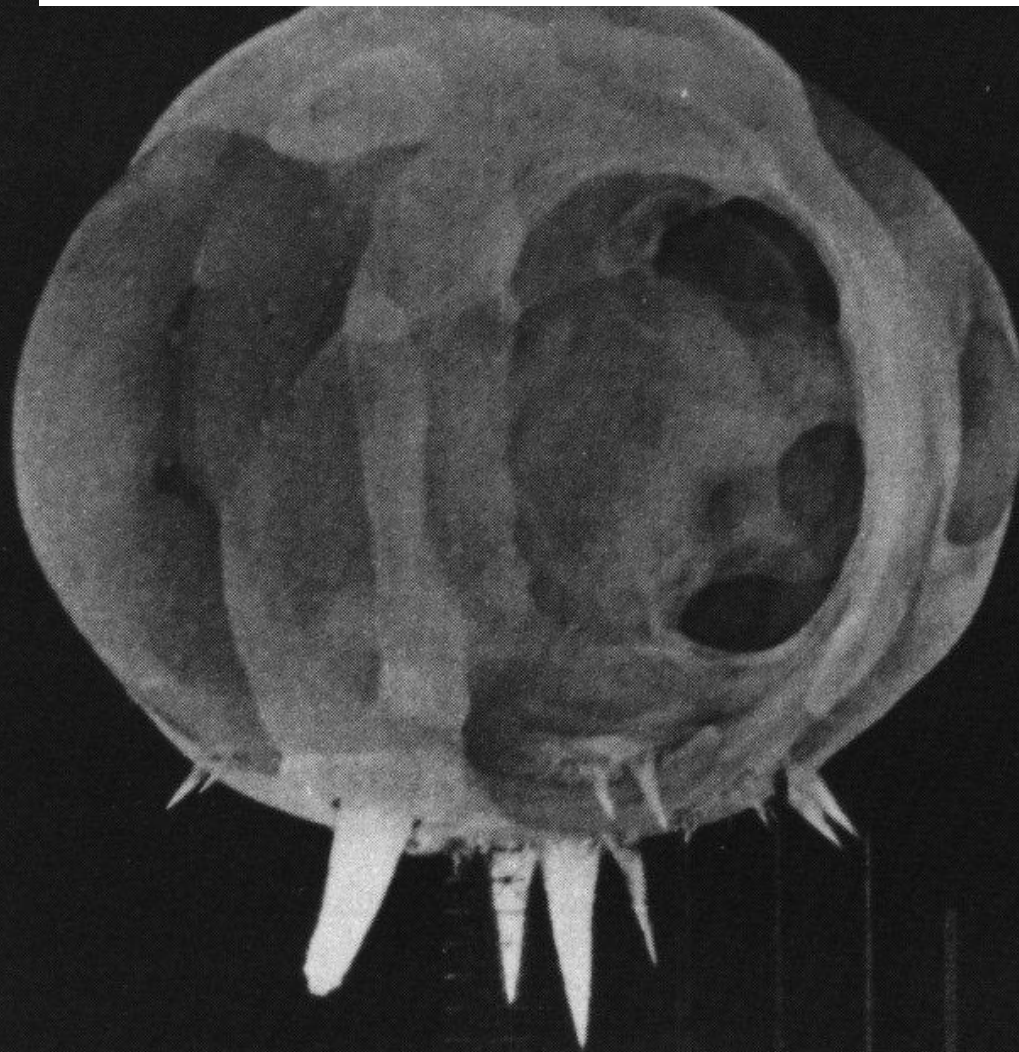




Political Map of the World, September 2008



Standoff Nuclear Blast



Standoff Nuclear Blast

Detonate a nuclear weapon close to the asteroid. The radiation pulse vaporizes surface material, making a strong reaction force.

Pros

Best "bang per kilogram" of all methods.

Proven technology.

May not even require rendezvous.

Can be fielded quickly.

Powerful enough to deflect an asteroid with a short lead time.

Thrust vector easily aimed.

Cons

Nukes in space.

Sensitive to poorly-known surface properties.

~3-fold unpredictability of resulting Δv .

Surface Nuclear Blast



0.016 SEC.
N

100 METERS

Surface Nuclear Blast

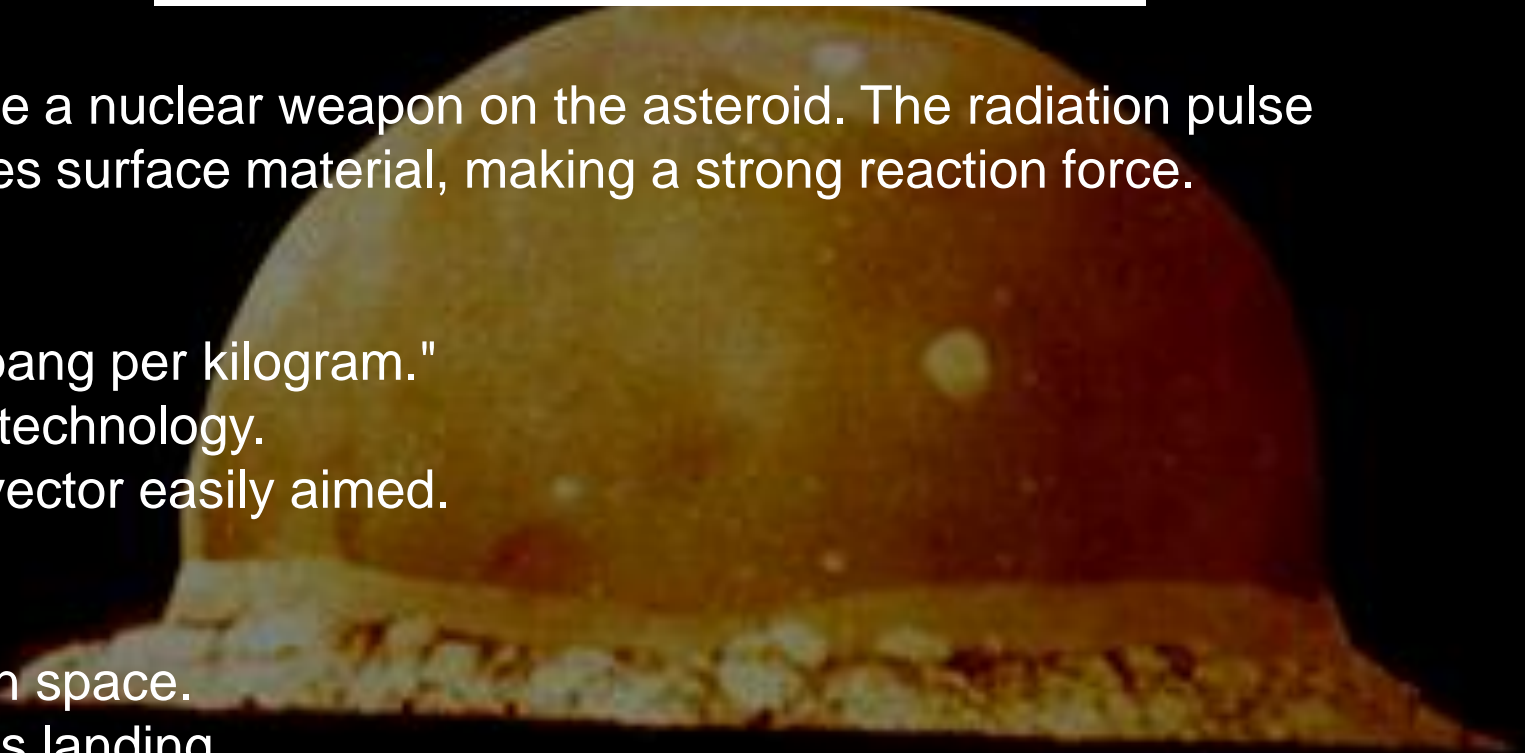
Detonate a nuclear weapon on the asteroid. The radiation pulse vaporizes surface material, making a strong reaction force.

Pros

Good "bang per kilogram."
Proven technology.
Thrust vector easily aimed.

Cons

Nukes in space.
Requires landing.
Sensitive to poorly-known surface properties.
~3-fold unpredictability of resulting Δv .
Might create fragments large enough to still be dangerous.



0.016 SEC
N

100 METERS

Buried Nuclear Blast



Buried Nuclear Blast

Hollywood-approved method. Detonate a nuclear weapon buried beneath the surface of the asteroid. The blast throws material into space, making a strong reaction force.

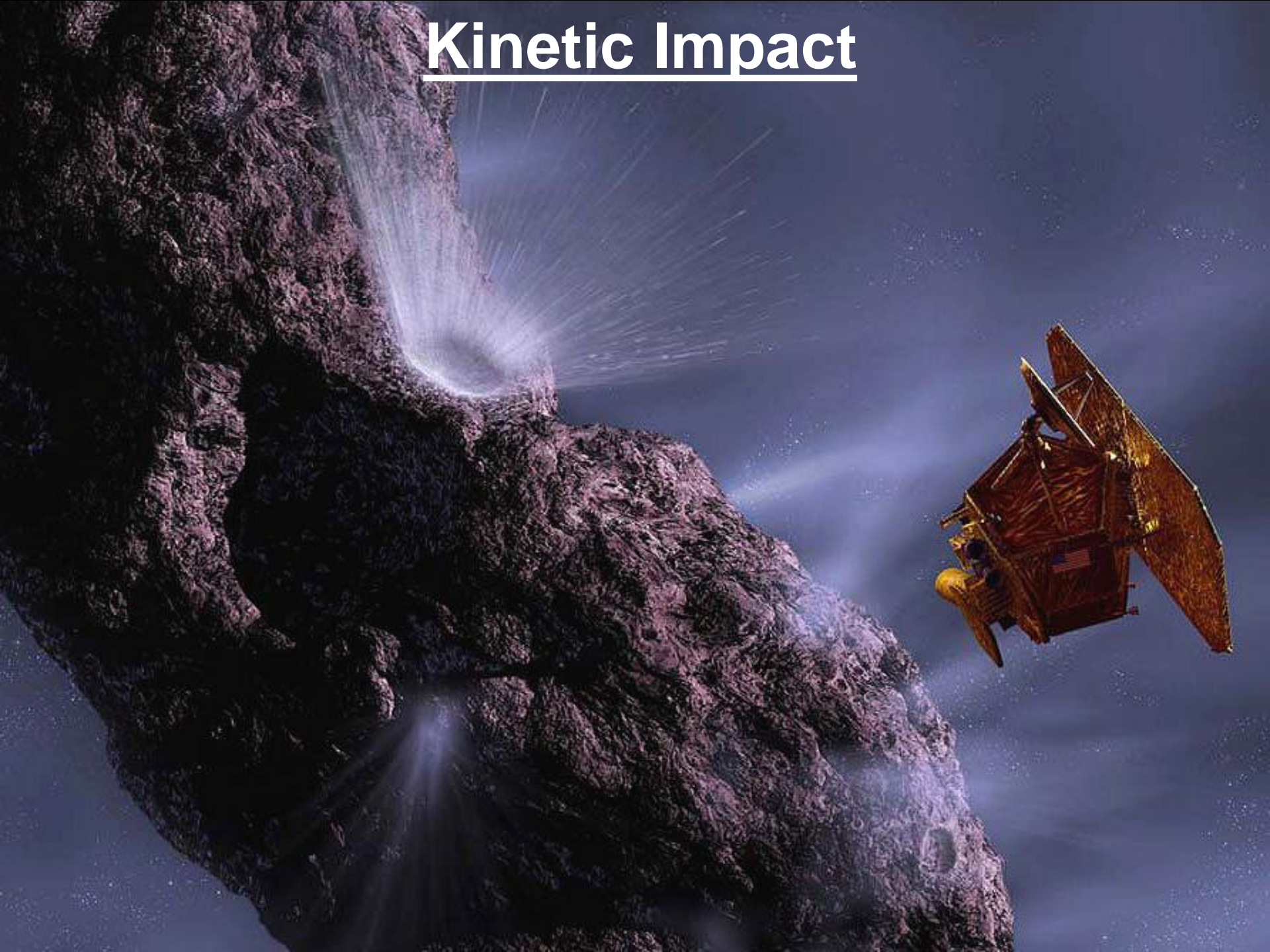
Pros

Good "bang per kilogram."
Proven technology.

Cons

Nukes in space.
Requires landing, anchoring, and drilling.
Sensitive to poorly-known bulk properties and internal structure.
~3-fold unpredictability of resulting Δv .
Might create fragments large enough to still be dangerous.

Kinetic Impact



Kinetic Impact

Hollywood-approved method. Place a heavy spacecraft where the asteroid will run into it. The resulting collision and crater excavation makes an orbit-changing reaction force.

Pros

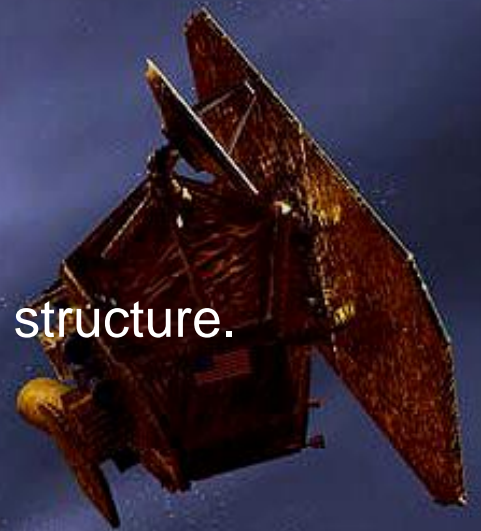
Proven technology.

Cons

Requires high-speed targeting.

Sensitive to poorly-known bulk properties and internal structure.

~3-fold unpredictability of Δv .



Attached Rocket Engine



Attached Rocket Engine

Land a rocket engine on the surface to push directly on the asteroid. Chemical, solar-electric, and nuclear-thermal options have been offered.

Pros

Predictable Δv .

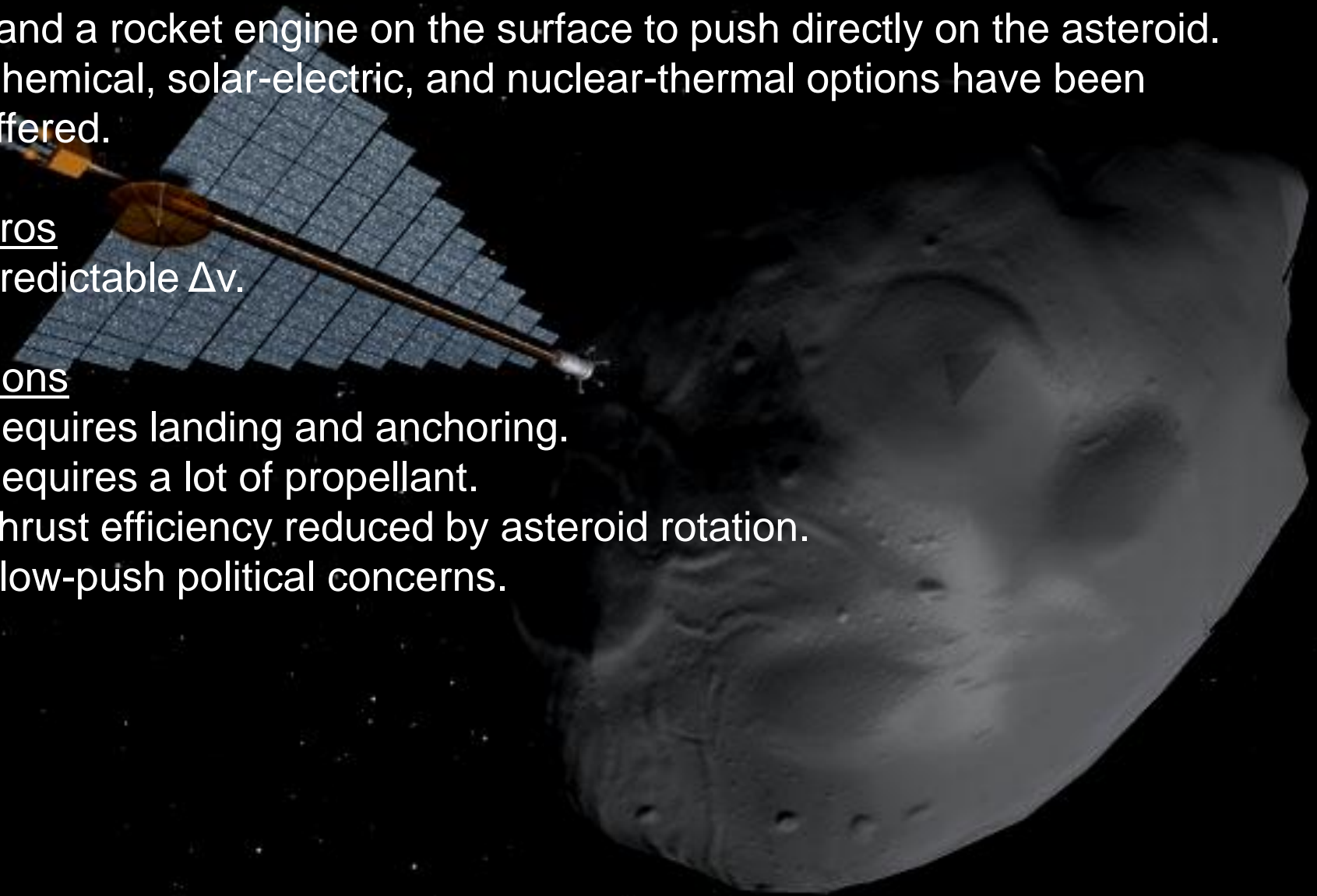
Cons

Requires landing and anchoring.

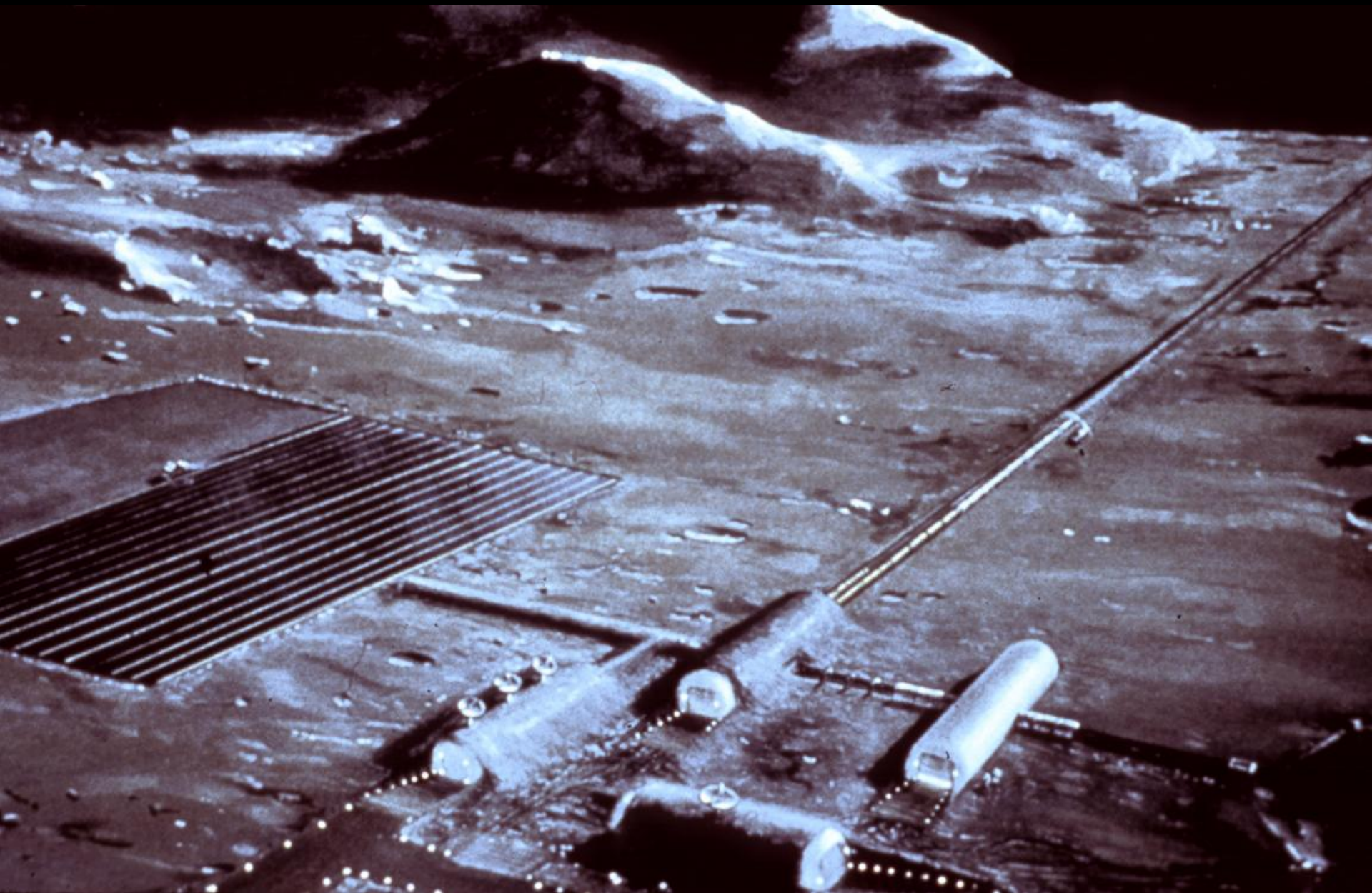
Requires a lot of propellant.

Thrust efficiency reduced by asteroid rotation.

Slow-push political concerns.



Attached Mass-Driver Engine



Attached Mass-Driver Engine

Land a mass driver on the surface and launch asteroid material into space to make a reaction force.

Pros

Uses local material instead of propellant brought from Earth.

Cons

Unproven technology.

Requires landing, anchoring, and excavation.

Thrust efficiency reduced by asteroid rotation.

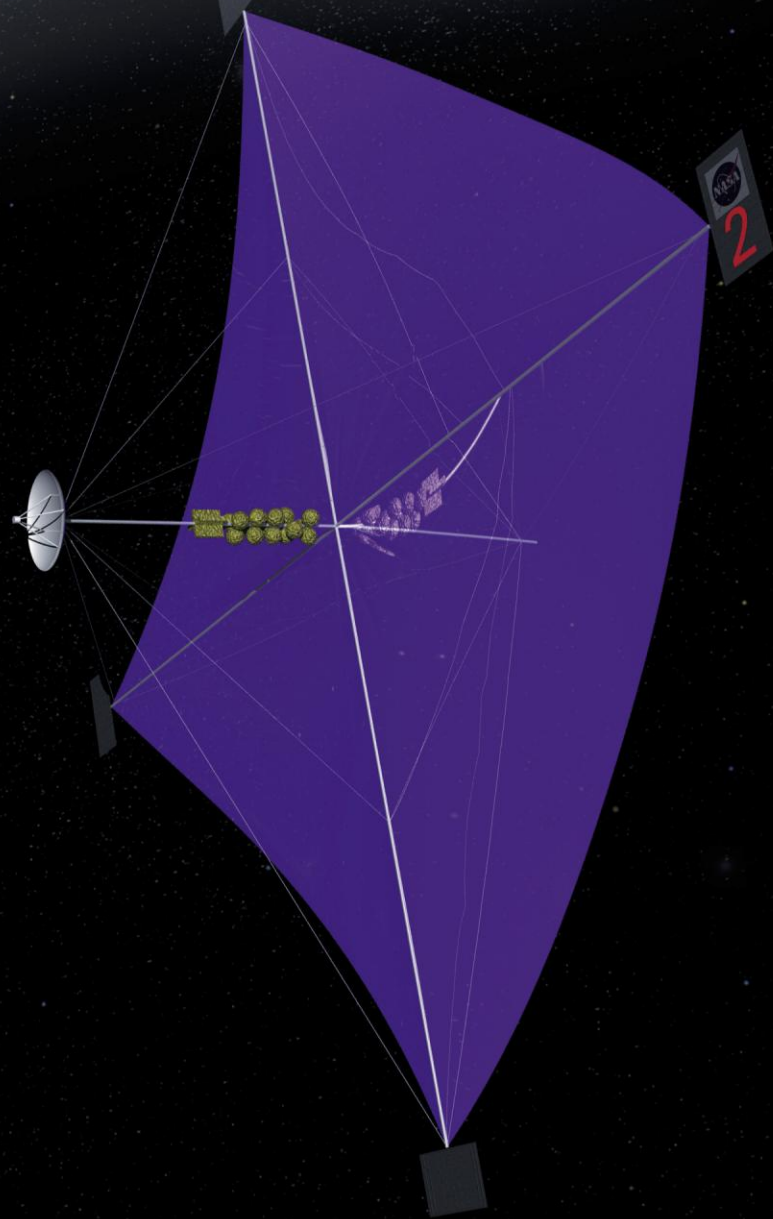
Slow-push political concerns.

Feedstock delivery technology does not exist.

Power source for mass driver is a technology challenge.



Attached Solar or Magnetic Sail



Attached Solar or Magnetic Sail

Tie a solar or magnetic sail to the asteroid and use radiation pressure or the solar wind to provide thrust.

Pros

No propellant needed.

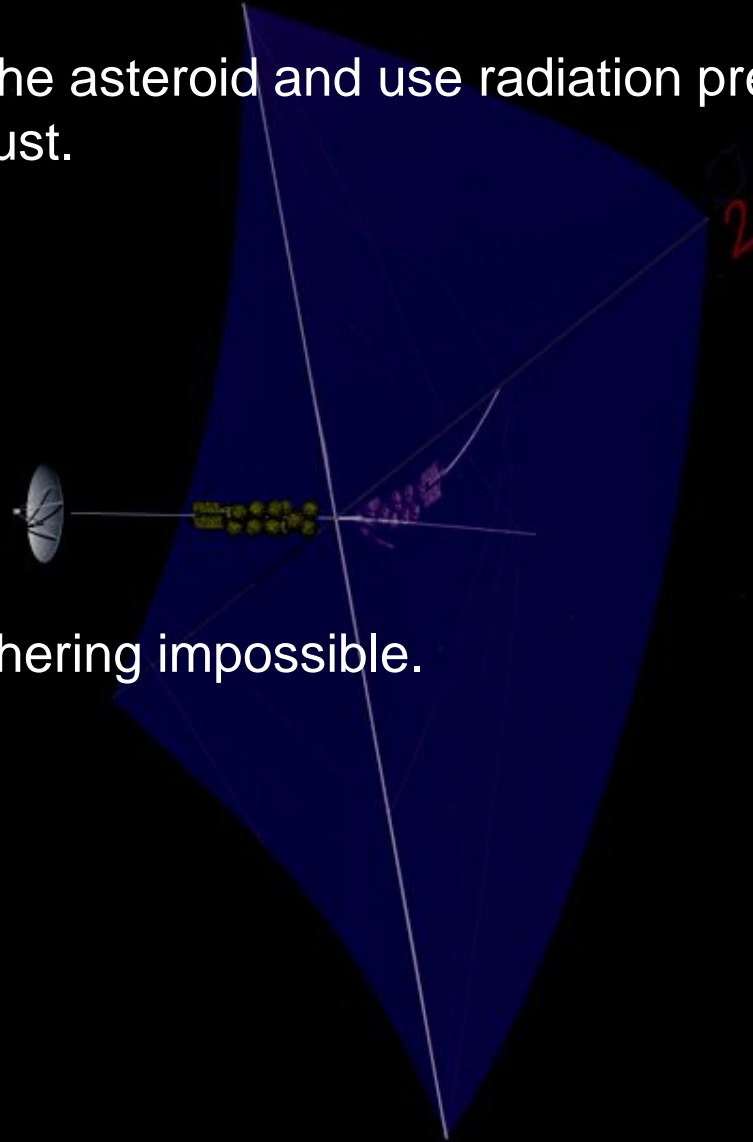
Cons

Unproven technology.

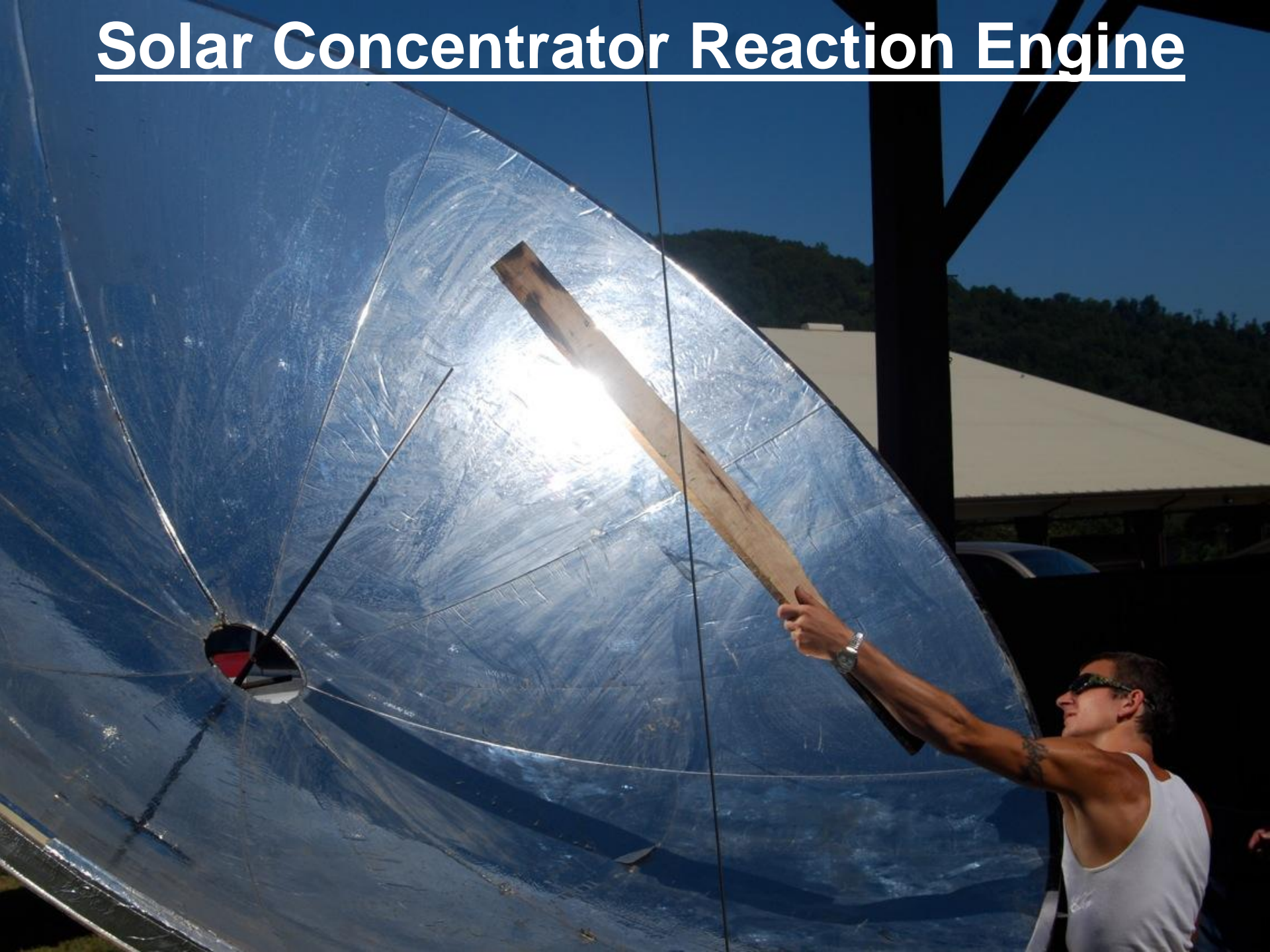
Requires anchoring.

Asteroid rotation may make tethering impossible.

Slow-push political concerns.



Solar Concentrator Reaction Engine



Solar Concentrator Reaction Engine

Park a large curved mirror next to the asteroid and focus sunlight on it. The material that boils off creates a reaction force.

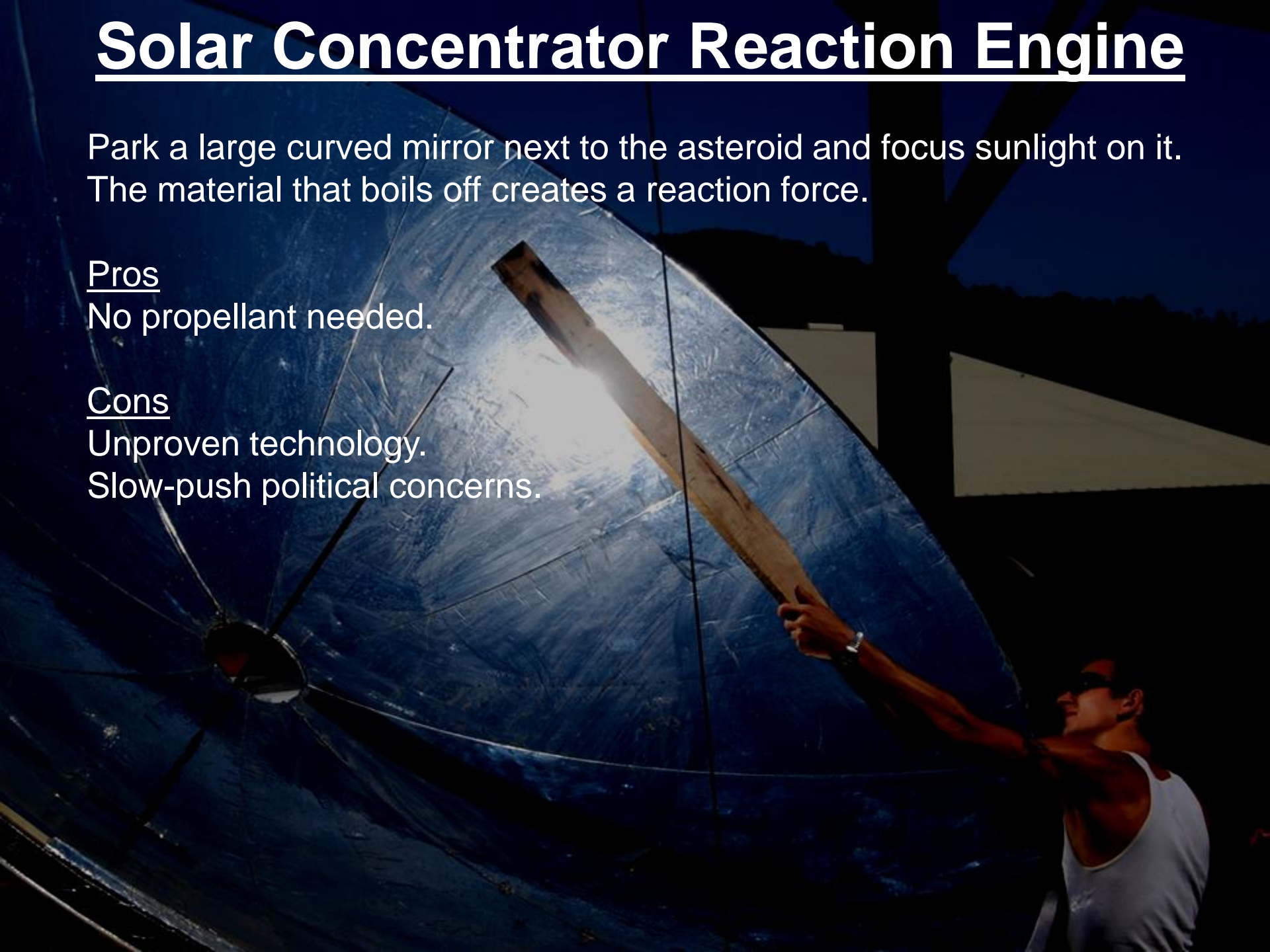
Pros

No propellant needed.

Cons

Unproven technology.

Slow-push political concerns.



Laser Reaction Engine



Laser Reaction Engine

Fire a powerful laser at the asteroid. The material that boils off creates a reaction force.

Pros

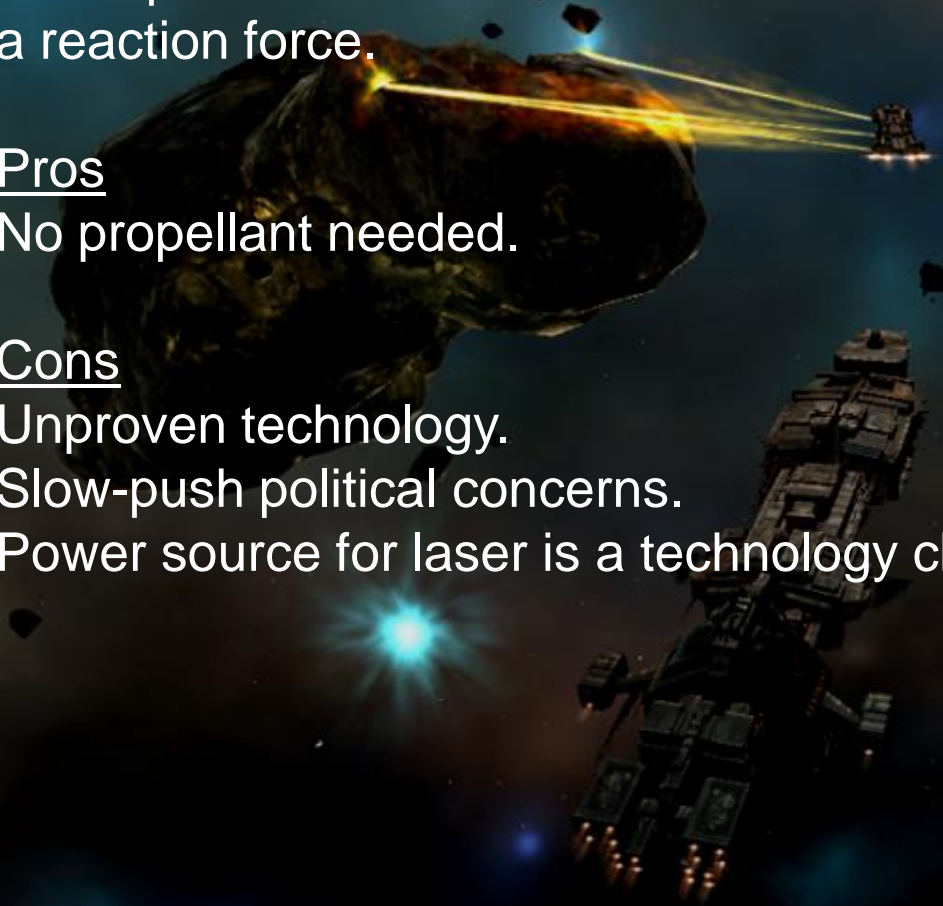
No propellant needed.

Cons

Unproven technology.

Slow-push political concerns.

Power source for laser is a technology challenge.



Gravity Tractor



Gravity Tractor

Pull the asteroid behind a hovering spacecraft, using gravity as a towline.

Pros

Proven technology.

Insensitive to asteroid mechanical properties and rotation.

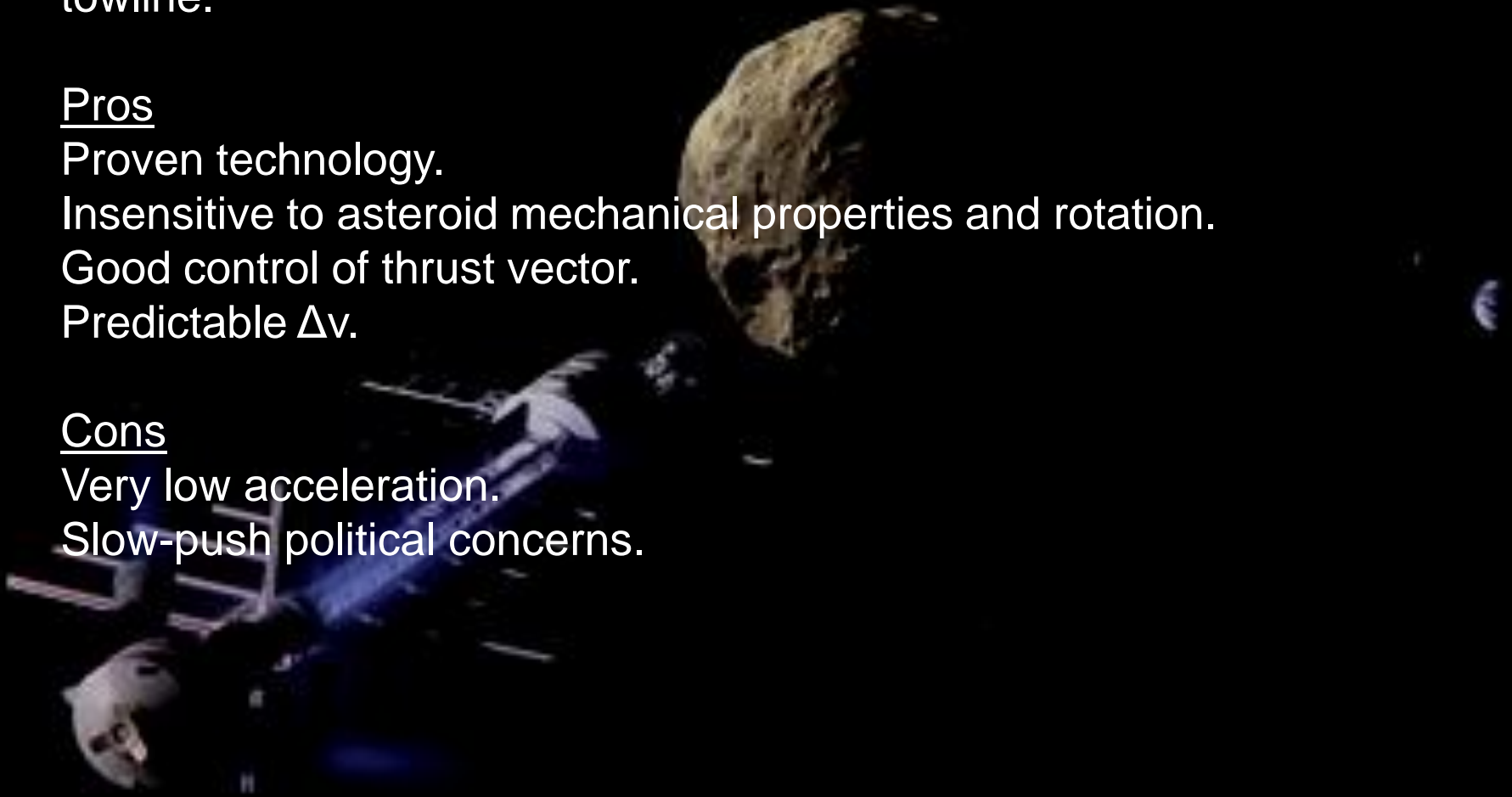
Good control of thrust vector.

Predictable Δv .

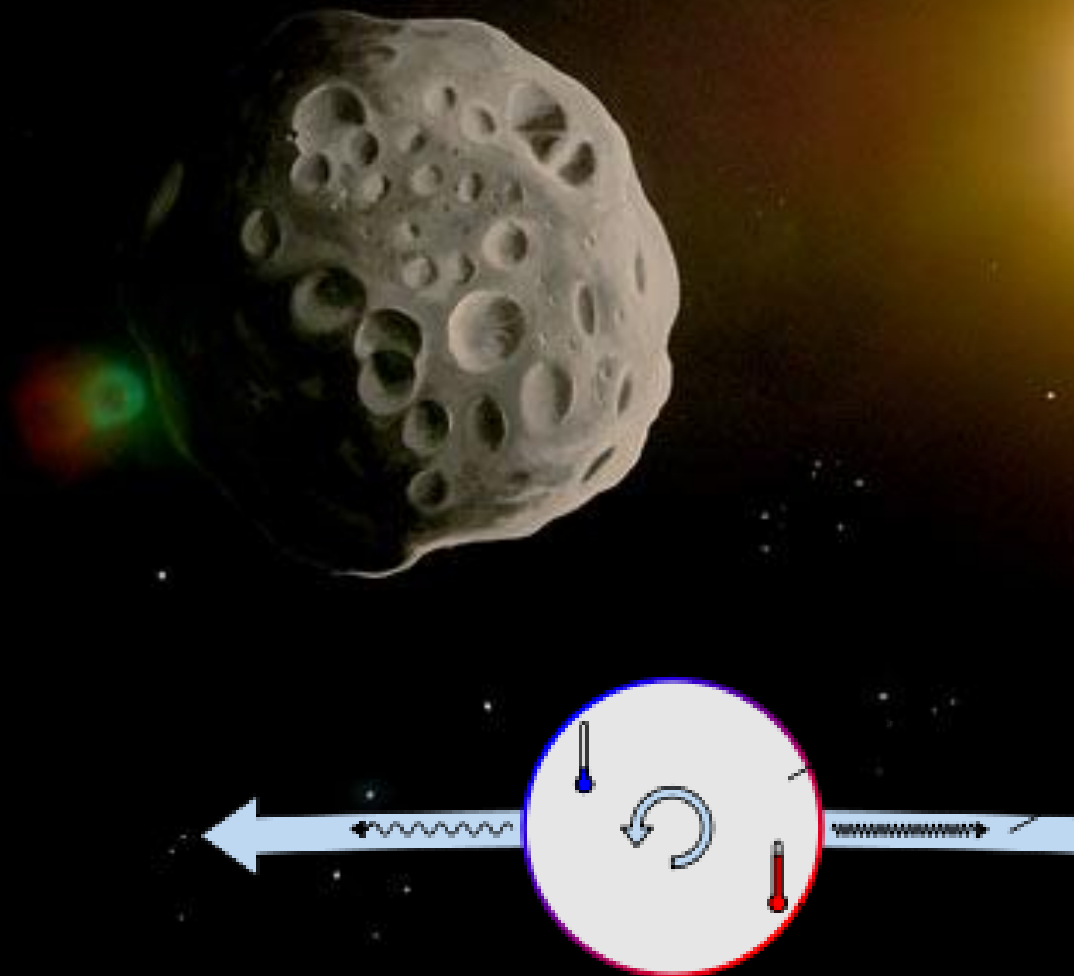
Cons

Very low acceleration.

Slow-push political concerns.



Albedo Modification (Yarkovsky Effect)



Albedo Modification (Yarkovsky Effect)

Paint the asteroid white (or black), changing its radiative properties. This will change the strength of the Yarkovsky effect.

Pros

No propellant needed.

Cons

Very low acceleration.

Poor control of thrust vector.

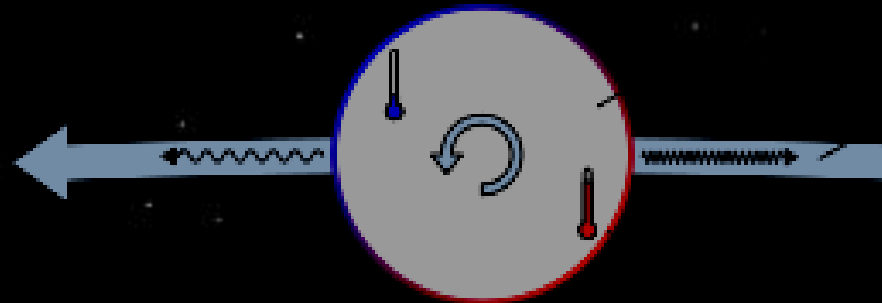
Unproven technology.

Very sensitive to asteroid surface properties.

Very sensitive to asteroid rotation speed and direction.

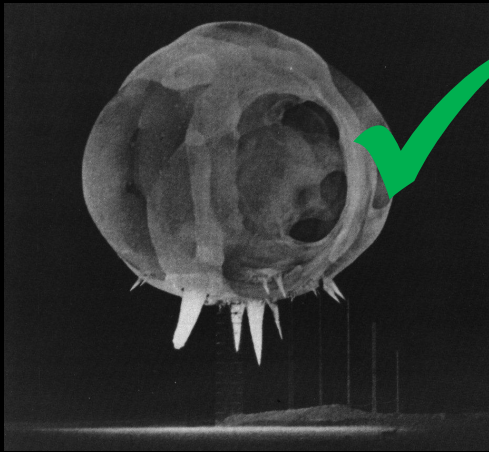
Slow-push political concerns.

Applying the paint is technically challenging.

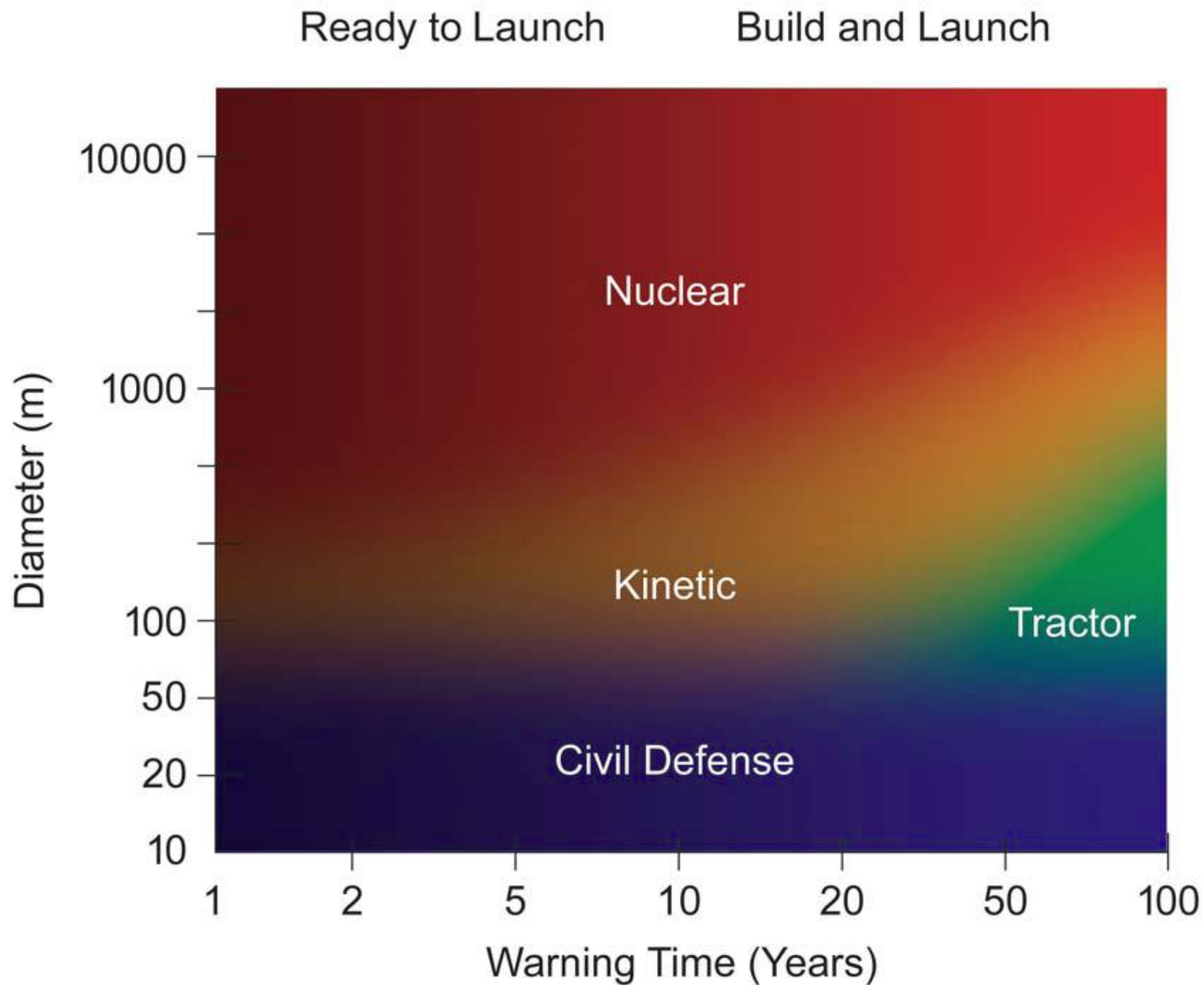


National Research Council

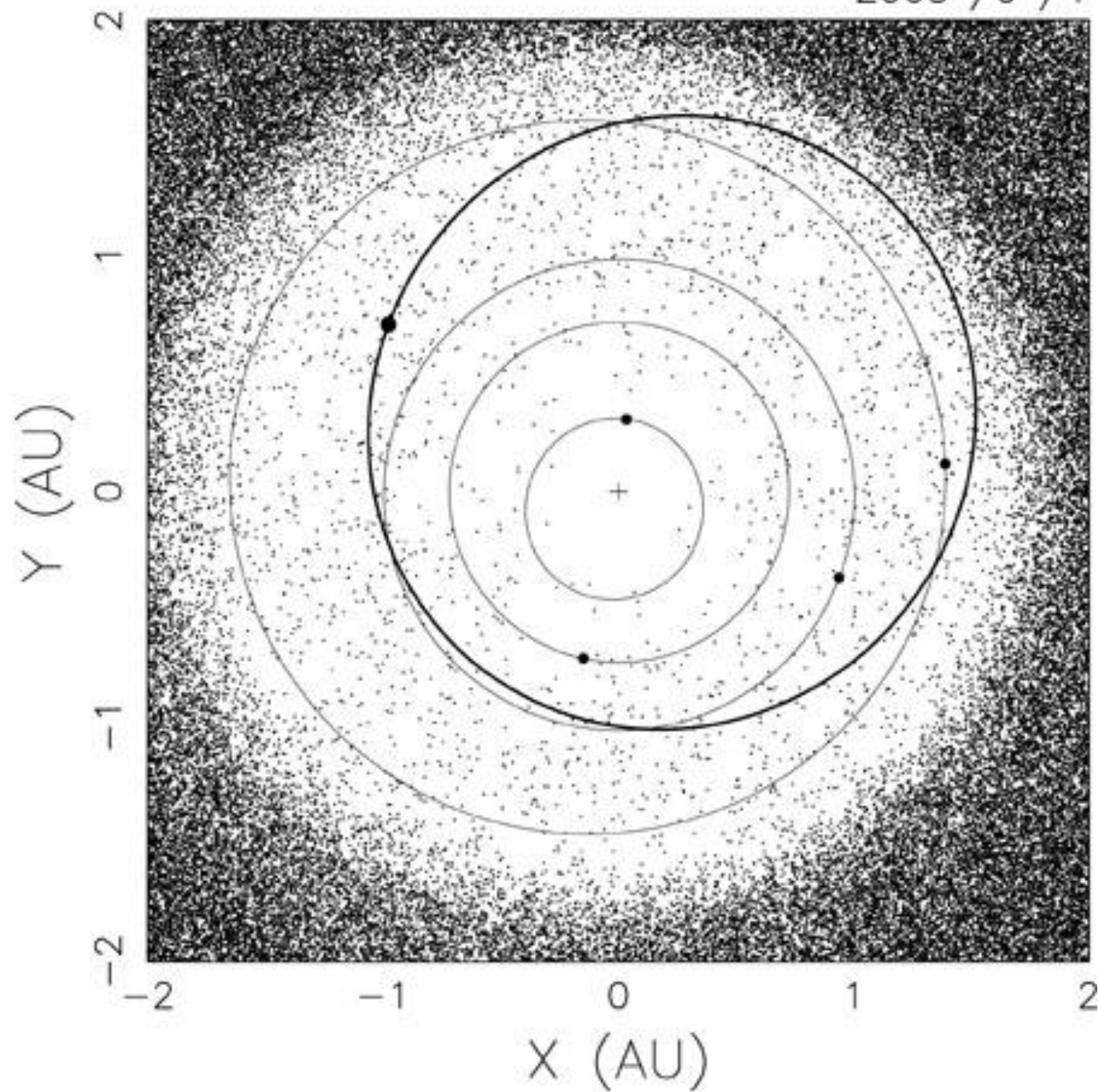
Defending Planet Earth: Near-Earth Object Surveys and Hazard Mitigation Strategies: Final Report (2009).



<http://www.nap.edu/catalog/12842.html>



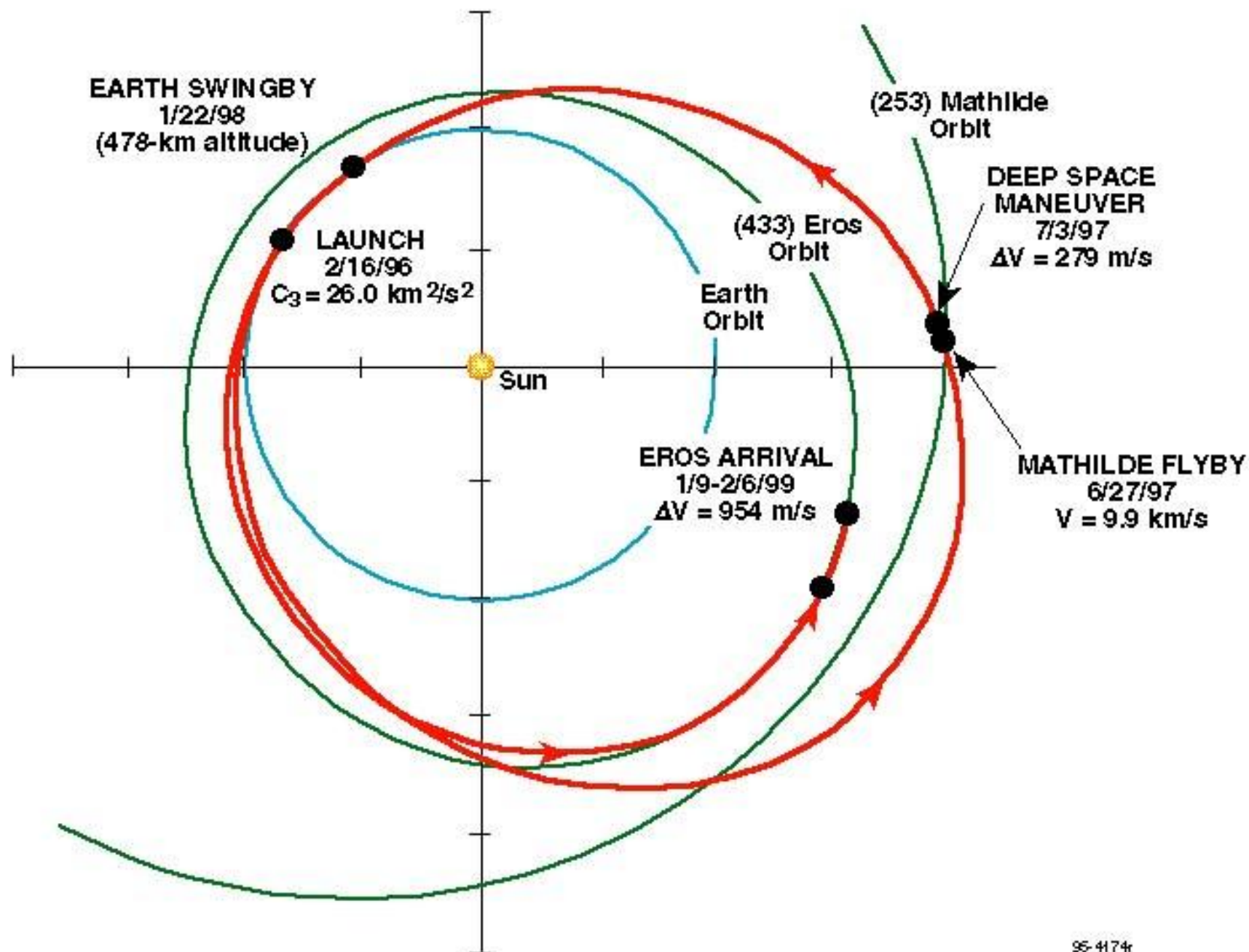
3. Human Missions to Asteroids

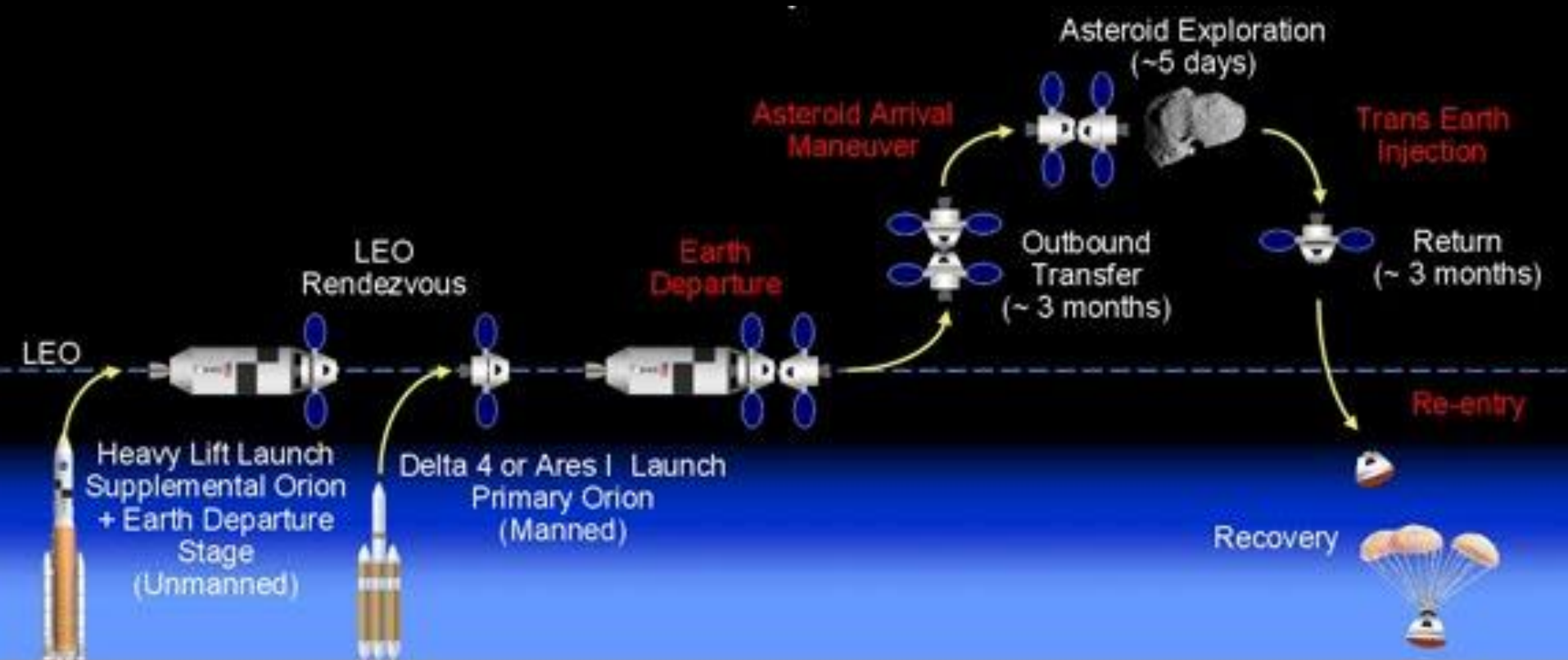






NEAR Trajectory Profile

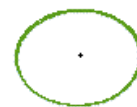




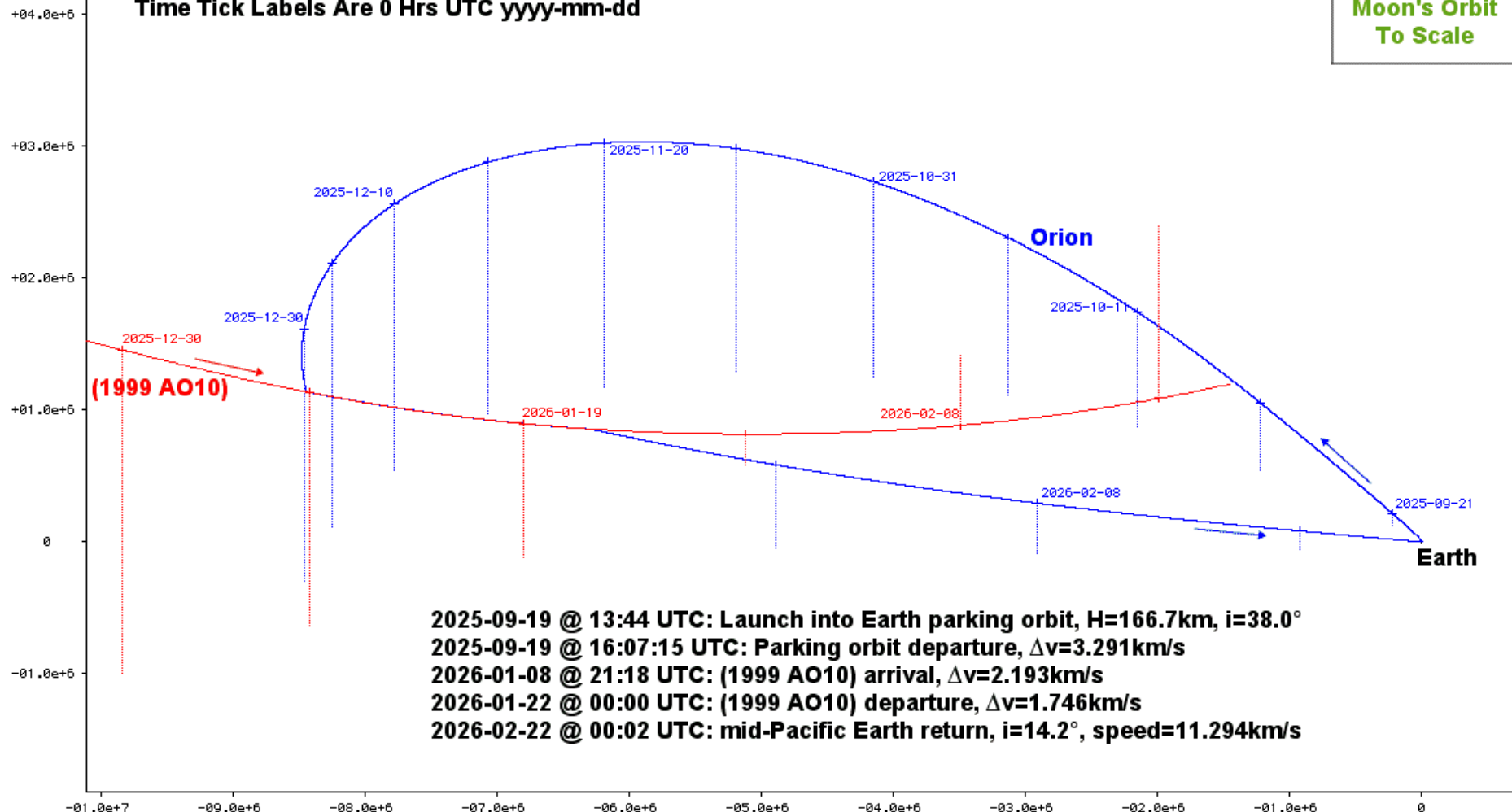
Mission To Asteroid (1999 AO10) In 2025/6

Dotted Lines Are Projections Onto Ecliptic Plane

Time Tick Labels Are 0 Hrs UTC yyyy-mm-dd



Moon's Orbit
To Scale



2025-09-19 @ 13:44 UTC: Launch into Earth parking orbit, $H=166.7\text{km}$, $i=38.0^\circ$

2025-09-19 @ 16:07:15 UTC: Parking orbit departure, $\Delta v=3.291\text{km/s}$

2026-01-08 @ 21:18 UTC: (1999 AO10) arrival, $\Delta v=2.193\text{km/s}$

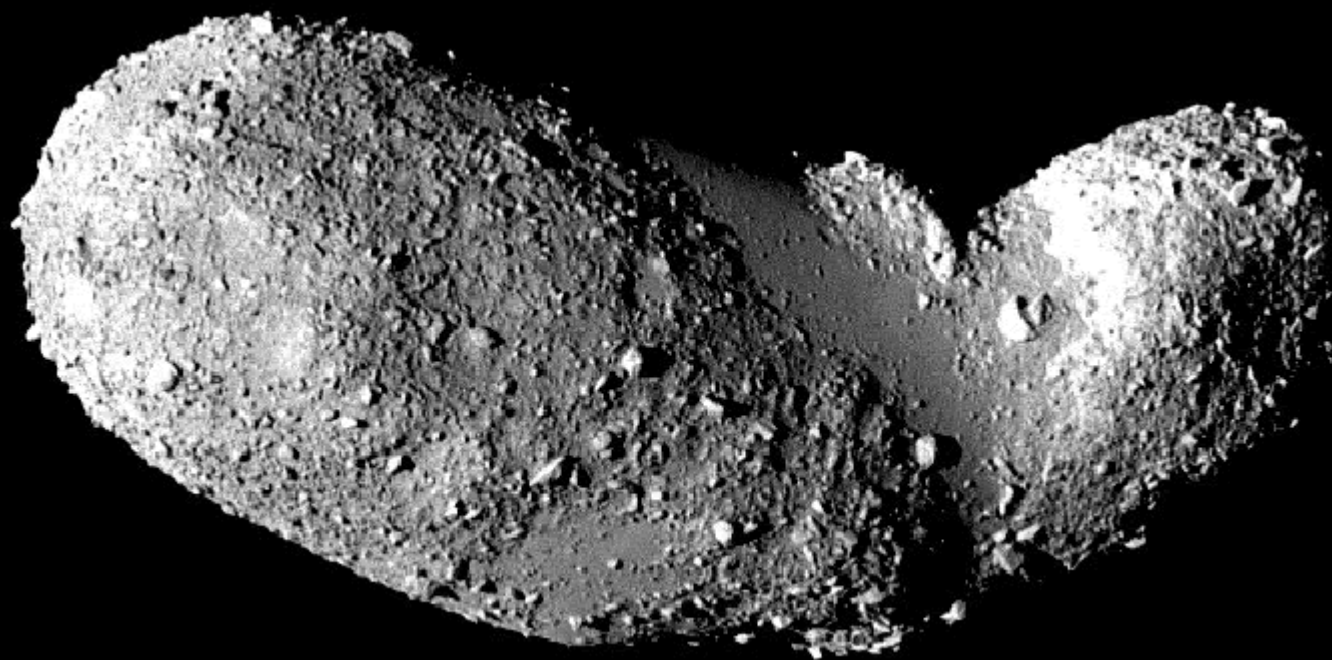
2026-01-22 @ 00:00 UTC: (1999 AO10) departure, $\Delta v=1.746\text{km/s}$

2026-02-22 @ 00:02 UTC: mid-Pacific Earth return, $i=14.2^\circ$, speed= 11.294km/s

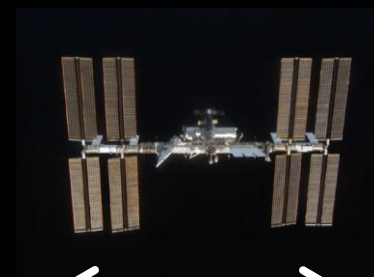
Km Units View From $Y= 0.0^\circ$, $P= 0.0^\circ$, $R= 45.0^\circ$

Earth-Centered J2KE Coordinate System

Visit to (1999 AO10)



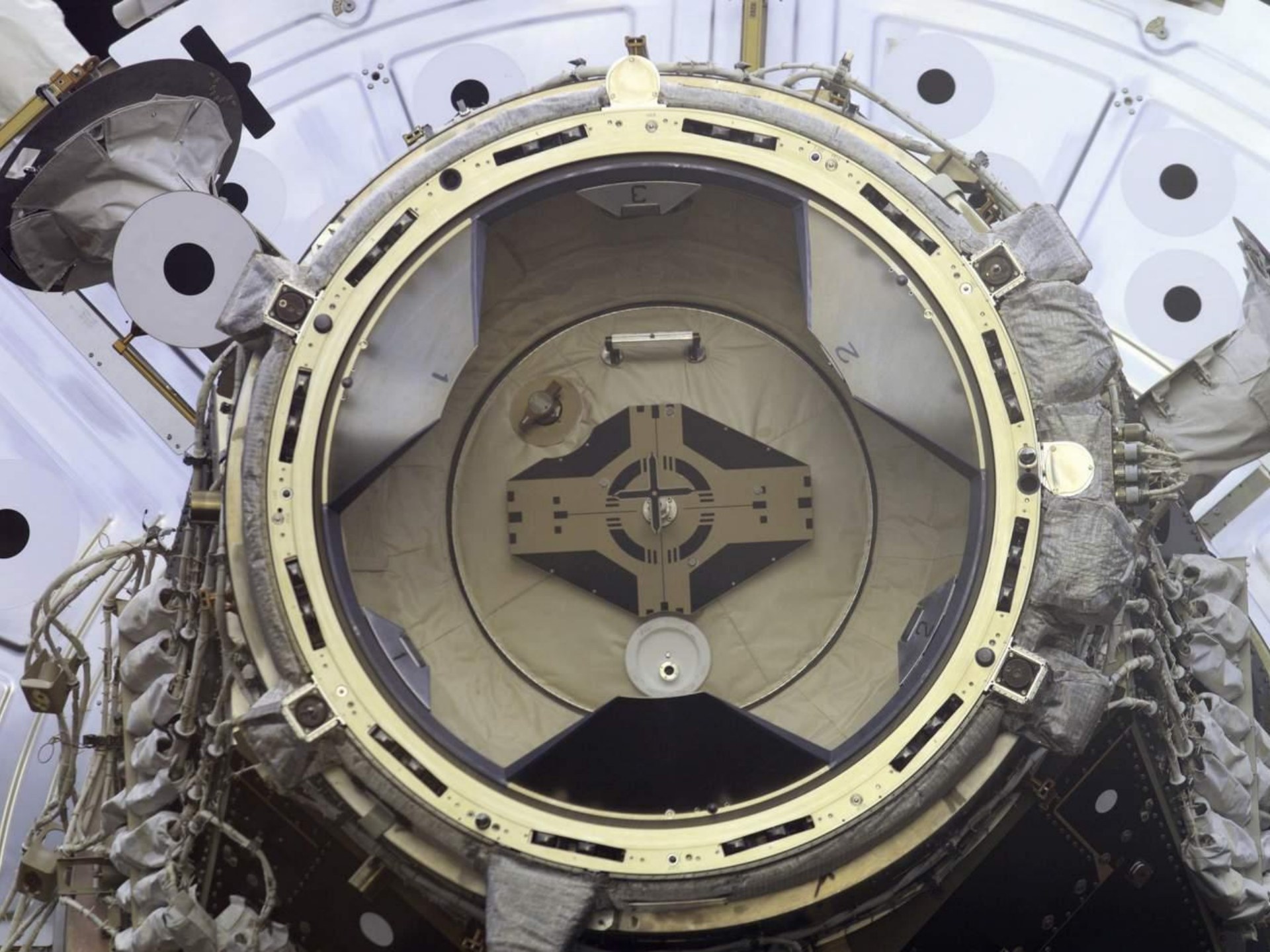
540 m



109 m









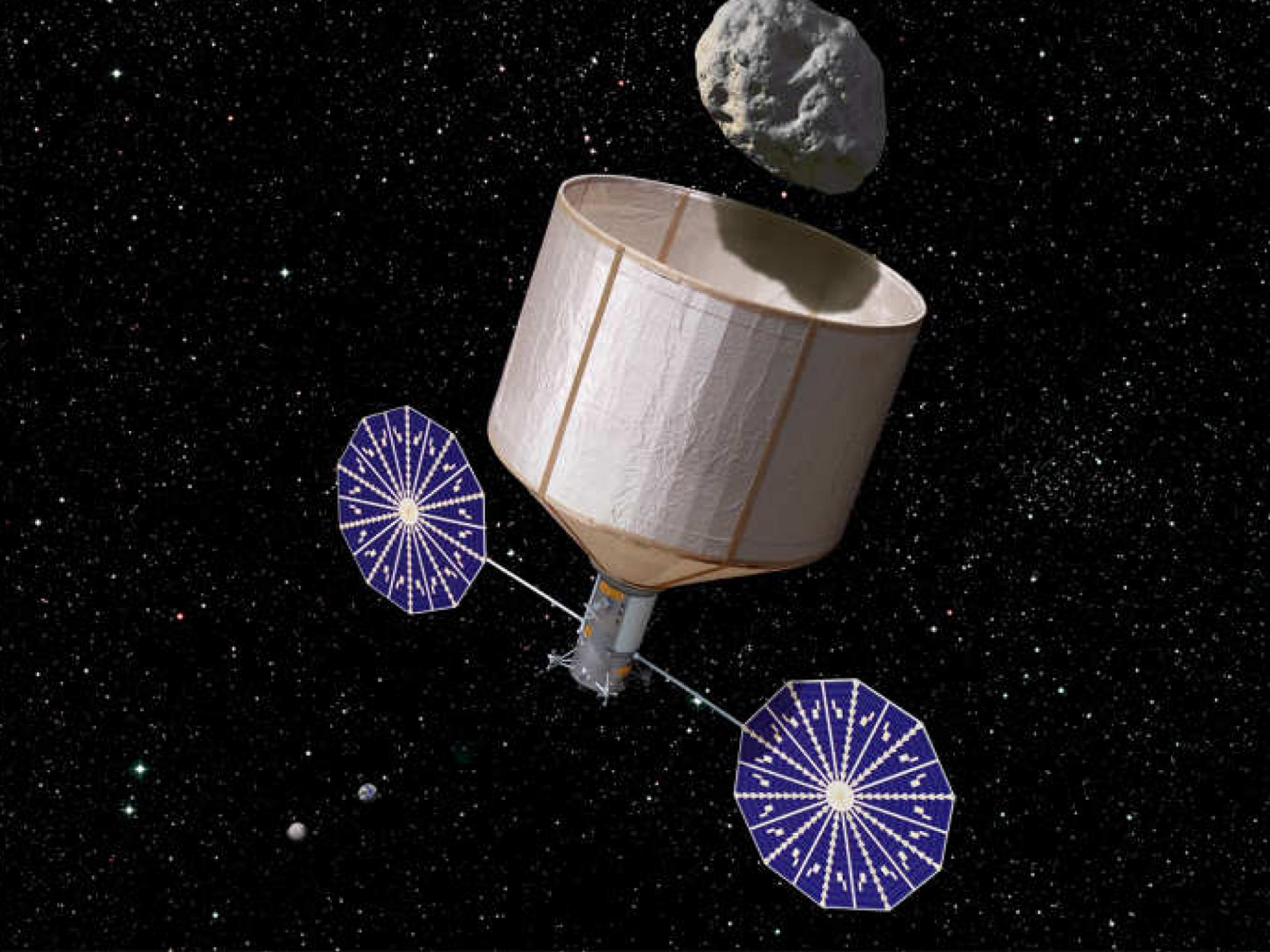


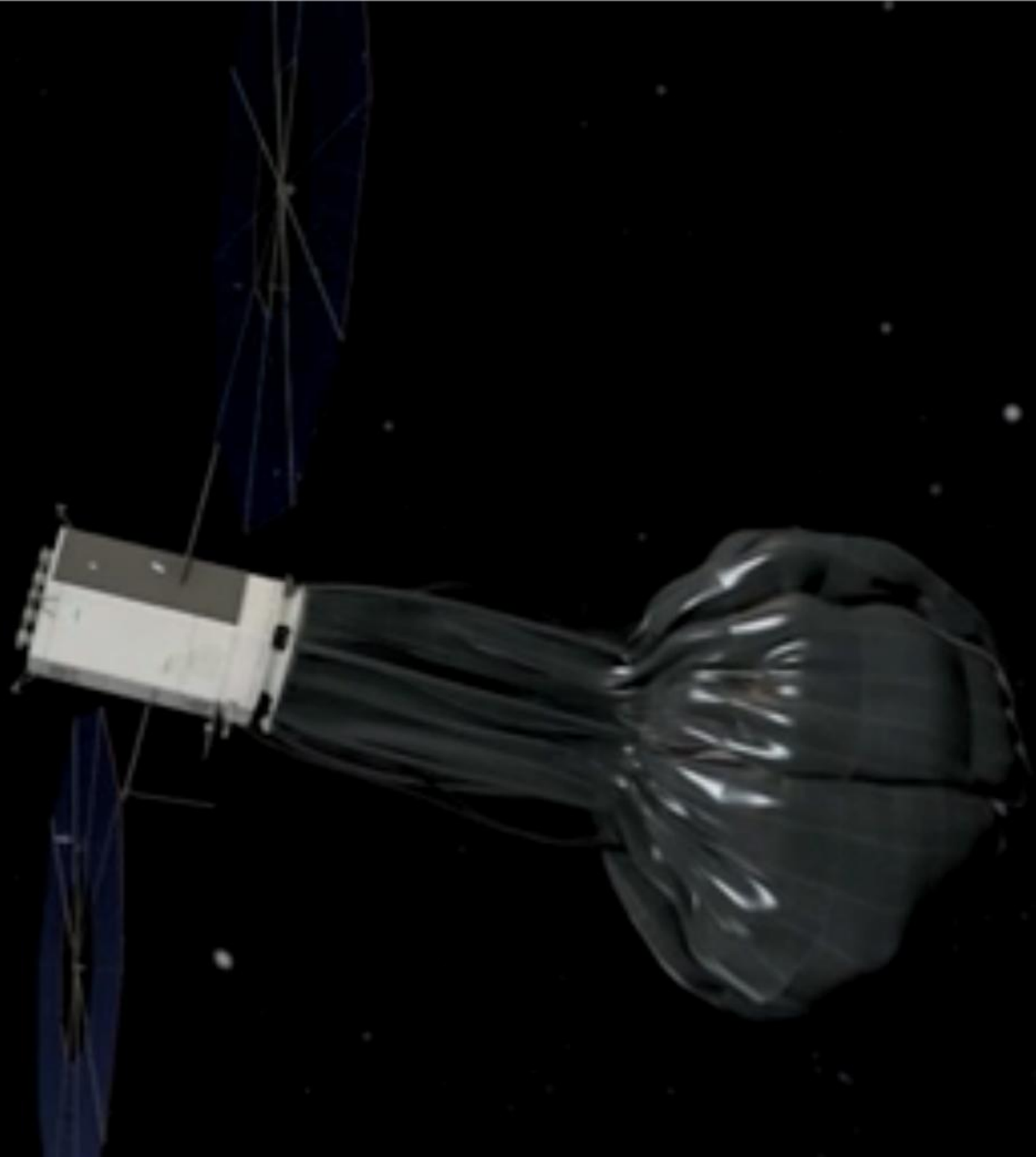


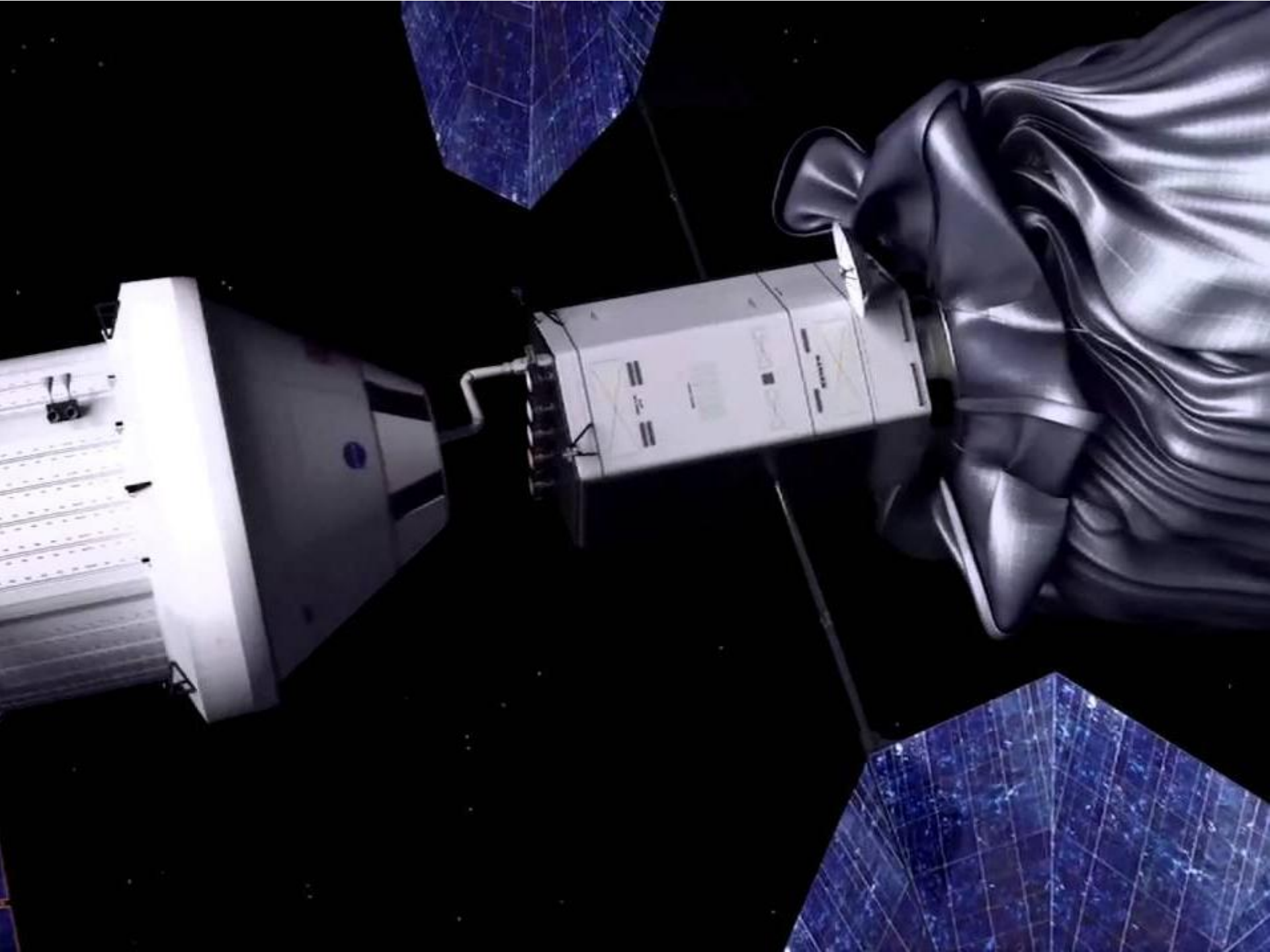


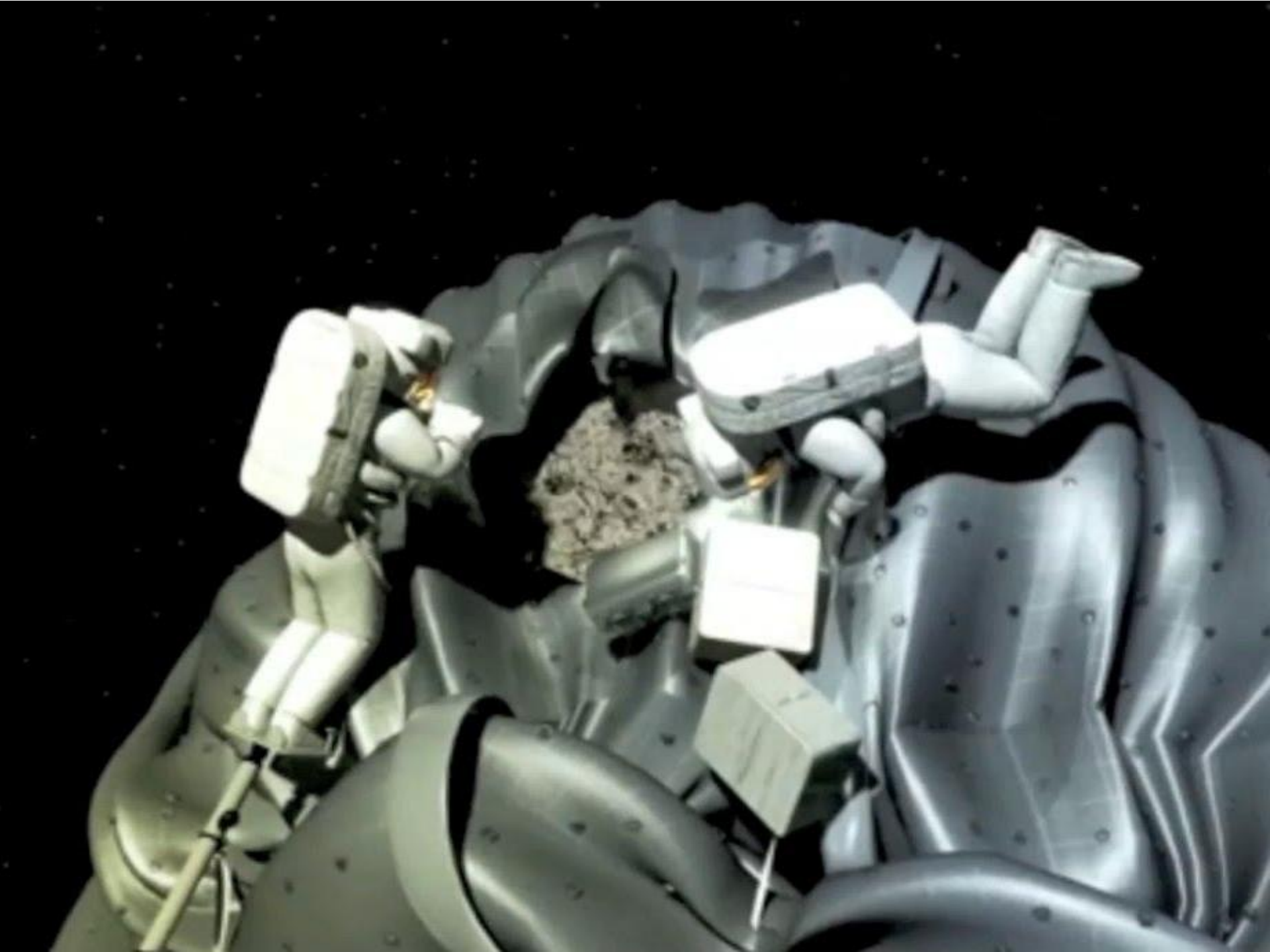








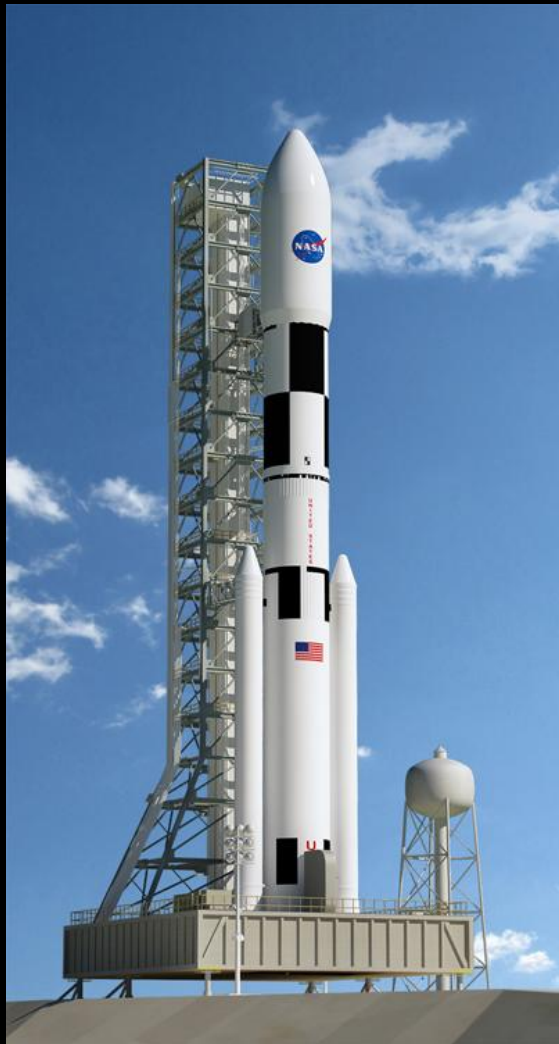








120 m



50 m



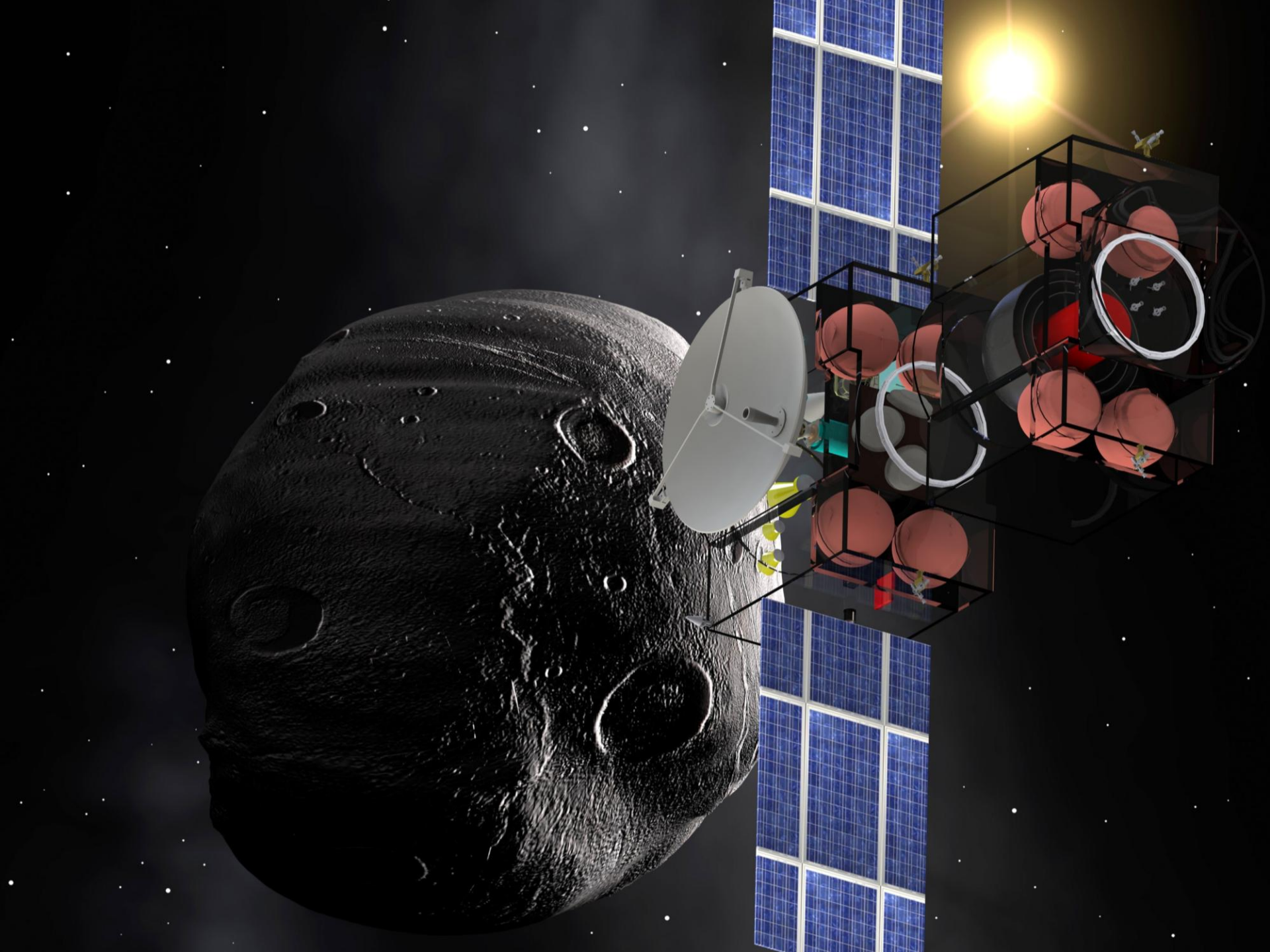
9 m



4. Conclusion









The End

Any questions?